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PHYSICS 20

EXAMPLES OF STUDENTS' RESPONSES

CLASSROOM
ASSESSMENT
MATERIALS

[redacted]

PHYSICS 20

EXAMPLES OF STUDENTS' RESPONSES

CLASSROOM
ASSESSMENT
MATERIALS

Alberta
EDUCATION

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Introduction

Purpose

The purpose of this document is to provide teachers, students, parents, and administrators with examples of students' responses that illustrate the provincial standards expected of students who complete Physics 20.

Contents

For each of the written or performance tasks, the *Examples of Students' Responses* document contains
- the student task
- the scoring criteria to be used by teachers to evaluate their students' work (these criteria can also be found in the *Teacher Manual*)
- examples of students' responses at each criteria "level"
- commentaries that illustrate and explain how the scoring criteria fit each response

Each student response in this document is reproduced as it appeared in the assessment; that is, in the students' own handwriting. Because of space limitations, the planning and drafting that may have preceded or accompanied some of the responses may not have been included. However, teachers and other readers should note that research has demonstrated a very strong relationship between the quality of planning and the degree of success in written expression.

Selection of Examples

The students' responses in this document were selected from those produced during the pilot testing of the Classroom Assessment Materials Project in May and June of 1996. A committee composed of Physics 20 teachers from different parts of the province reviewed and validated the assessments and scoring criteria, then selected students' responses.

These examples of students' work illustrate the provincial standards for students who complete Physics 20.

Considerations

Please note that
- the examples presented illustrate specific standards (scoring criteria), but are not necessarily typical of the responses submitted
- the selected responses represent only a few of the possible approaches to each task. None of the examples is intended to serve as a model of a particular approach
- you should consider each student example in light of the constraints of the assessment situation. Under assessment conditions, most students are able to prepare responses that must be considered as first draft only

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In addition to this *Examples of Students' Responses*, the Physics 20 Classroom Assessment Materials include a complete set of *Student Materials* and a *Teacher Manual* in separate booklets.

End-of-Course Exam

- ***Written Response 1***
- ***Written Response 2***

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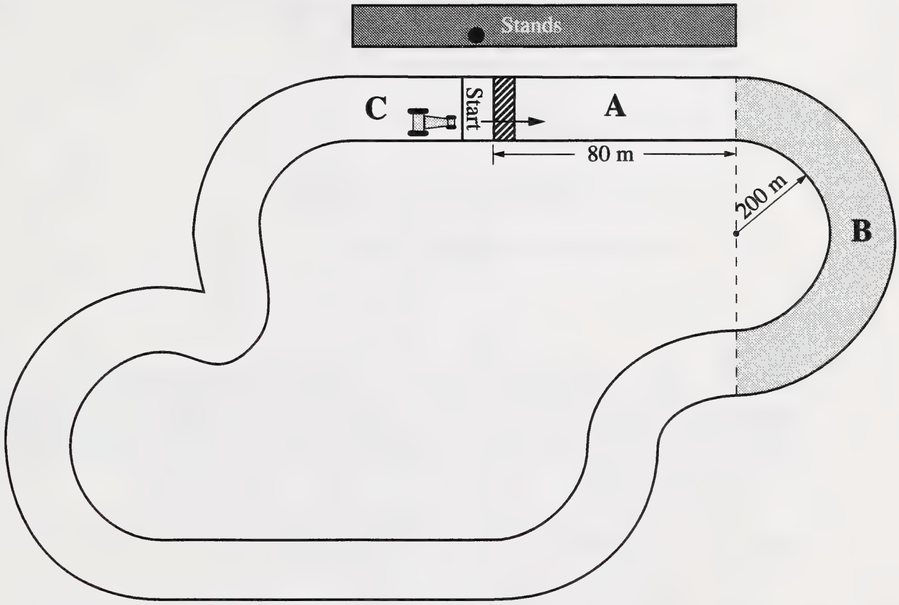
Written Response 1

The task as it appears in the Teacher Manual:

Use the following information to answer the next question.



From the starting line, a race car accelerates uniformly along the 80 m straightaway, **A**, before entering the 200 m curve, **B**. To travel the shortest distance, the race car drives as close to the inside edge of the race track as possible. The race car has a mass of 1200 kg.

Written Response — 10 marks

1. **a.** The race car starts from rest and accelerates uniformly at 2.4 m/s^2 along the straightaway. What is its speed when it enters the first turn?

There are three checks for **a**:

1. Stating $v_f^2 = v_i^2 + 2ad$ (communication)
2. Correctly substituting values into formula
3. Calculating an answer of 20 m/s

b. While going around the curve, **B**, the driver wants to go as fast as possible but does not want the car to skid. For the road conditions, the force of friction between the tires and the road is equivalent to 3.2 times the weight of the race car. What is the maximum speed the car can safely have? (**Note**: When $F_c > F_f$, the race car will skid.)

There are six checks for **b**:

4. Stating $F_f = 3.2\ W$ or $3.2\ F_g$ (communication)

5. Stating F_g or $W = ma$ (communication)

6. Stating $F_c = F_f$ (communication)

7. Implicitly stating $F_c = \frac{mv^2}{R}$

8. Correctly substituting values throughout

9. Calculating an answer of 79 m/s

c. A spectator in the stands near the start line observes that the loudness of the engines increases and then decreases as the race cars travel from **C** to **A**. This is not the only change that is observed as the race cars travel from **C** to **A**. Describe and explain what other change occurs, in terms of sound waves.

There are six checks for **c**:

10. The pitch or frequency increases

11. The pitch or frequency decreases

12. The increase happens as the car approaches the spectator

13. The decrease happens as the car leaves

14. The increase occurs because the number of wave fronts per second increases (or the wavelength decreases)

15. The decrease occurs because the number of wave fronts per second decreases (or the wavelength increases)

Use this chart to convert the number of checks the response received to the student's mark out of 10 on this question.

Conversion of Check Marks to Marks

Check Marks	Marks
15	10
13–14	9
12	8
11	7
9–10	6
7–8	5
6	4
4–5	3
3	2
1–2	1
0	0

General Trends

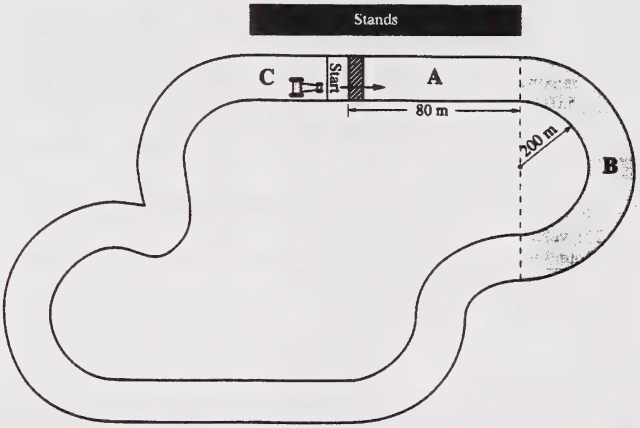
In part **b.** of this question, students tend to display very weak mathematical communication skills. Although the substitutions show students understand that the forces are equivalent, they communicate this only implicitly.

In part **c.** of this question, minor changes were made to the wording of the question in response to comments from pilot teachers.

Student Example 1

This response would receive a score of 8 out of 10.

Use the following information to answer the next question.



From the starting line, a race car accelerates uniformly along the 80 m straightaway, **A**, before entering the 200 m curve, **B**. To travel the shortest distance, the race car drives as close to the inside edge of the race track as possible. The race car has a mass of 1200 kg.

Written Response — 10 marks

1. **a.** **The race car starts from rest and accelerates uniformly at 2.4 m/s² along the straightaway. What is its speed when it enters the first turn?**

Find Speed

$V_f^2 = V_i^2 + 2ad$

$V_f^2 = (0\frac{m}{s})^2 + 2(2.4\frac{m}{s^2} \times 80m)$

$V_f^2 = 0\frac{m^2}{s^2} + 384\frac{m^2}{s^2}$

$V_f^2 = 384\frac{m^2}{s^2}$

$V_f = 19.596\frac{m}{s}$

∴ The racecar's speed as it enters the first turn is $20\frac{m}{s}$

Continued

b. **While going around the curve, B, the driver wants to go as fast as possible but does not want the car to skid. For the road conditions, the force of friction between the tires and the road is equivalent to 3.2 times the weight of the race car. What is the maximum speed the car can safely have? (Note: When $F_c > F_f$, the race car will skid.)**

I Find Frictional Force

$F_f = 3W$

$= 3(mg)$

$= 3(1200\,kg \times -9.81\,\frac{m}{s^2})$

$F_f = -35\,316\,N$

II Find Maximum Speed

$F_c = \frac{mv^2}{R}$

$v = \sqrt{\frac{R F_c}{m}}$

$= \sqrt{\frac{200\,m \times 35\,316\,N}{1200\,kg}}$

$= 76.72027\,\frac{m}{s}$

$\therefore$ The maximum speed the car can safely have is $7.7 \times 10\,\frac{m}{s}$.

c. **A spectator in the stands near the start line observes that the loudness of the engines increases and then decreases as the race cars travel from C to A. This is not the only change that is observed. Describe what other change occurs, in terms of sound waves.**

Another change that would occur would be that of the pitch of the engines. This is caused by the Doppler Effect. Pitch is a sensory characteristic which is affected by frequency. The Doppler Effect states that as the source of a sound nears you, its frequency will increase due to the relative position of the sound. As the sound nears you, its relative frequency increases, causing an apparent increase in frequency and therefore pitch. As the sound gets farther away, the relative frequency decreases and the pitch is lowered accordingly. This accounts for the other change the spectator observes.

Commentary

In part **a.**, the student states the formula, substitutes correctly, and states the answer with the correct units and the correct number of significant digits, thus receiving all 3 checks.

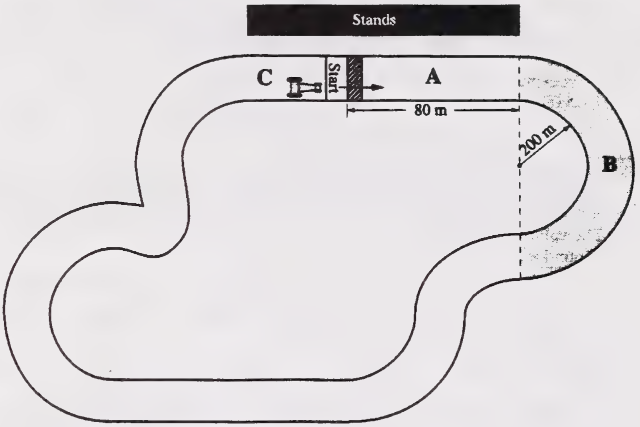
The response in part **b.** receives 4 checks. Because of a copying error (3W rather than 3.2 W), the student loses either check 4 or 8, but not both. The communication of check 6, $F_c = F_f$, is implied, not stated, so the check is not awarded. The answer of 7.7 × 10 m/s is consistent with the calculation shown. This student is making connections beyond simple formulas from the data sheet.

In part **c.**, the student clearly identifies the change in pitch and relates it correctly to the motion of the race car for checks 10 through 13. The student also receives check 14 because of the attempt to explain why the changes occur. This student is confident in applying physics to a real world situation. The total of 12 checks converts to a mark of 8.

Student Example 2

This response would receive a score of 5 out of 10.

Use the following information to answer the next question.



From the starting line, a race car accelerates uniformly along the 80 m straightaway, **A**, before entering the 200 m curve, **B**. To travel the shortest distance, the race car drives as close to the inside edge of the race track as possible. The race car has a mass of 1200 kg.

Written Response — 10 marks

1. **a.** The race car starts from rest and accelerates uniformly at 2.4 m/s^2 along the straightaway. What is its speed when it enters the first turn?

$m = 1200\,kg$

$a = 2.4\,m/s^2$

$\vec{d}_s = 80\,m$

$r_c = 200\,m$

$V_f^2 = V_i^2 + 2ad$

$V_f^2 = 0\frac{m}{s} + 2 \times 2.4\,\frac{m}{s^2} \times 80\,m$

$\sqrt{V_f^2} = \sqrt{384\,\frac{m^2}{s^2}}$

$V_f = 20\,\frac{m}{s}$

$20\,\frac{m}{s} \times \frac{1\,km}{1000\,m} \times \frac{3600\,s}{1\,h}$

$\frac{71\,km}{h}$

Therefore the final vebcity while leaving the straightaway is $20\,\frac{m}{s}$

Continued

b. **While going around the curve, B, the driver wants to go as fast as possible but does not want the car to skid. For the road conditions, the force of friction between the tires and the road is equivalent to 3.2 times the weight of the race car. What is the maximum speed the car can safely have? (Note: When $F_c > F_f$, the race car will skid.)**

$V = 25 \frac{m}{s}$

$F_c = F_f$

$\frac{\cancel{m}v^2}{r} = 3.2 \times \cancel{m}$

$\frac{v^2}{r} = 3.2$

$v^2 = 3.2r$

$v^2 = 3.2 \times 200m$

$\sqrt{v^2} = \sqrt{640}$

c. **A spectator in the stands near the start line observes that the loudness of the engines increases and then decreases as the race cars travel from C to A. This is not the only change that is observed. Describe what other change occurs, in terms of sound waves.**

The sound waves seem to have a higher frequency when the car travels from C to A.

Commentary

In part **a.**, the student states the formula, substitutes correctly, and states the answer with the correct units and the correct number of significant digits, thus receiving all 3 checks.

In part **b.**, the student receives checks 6, 7, and 8. A formula from the data page, $F_c = mv^2/r$, is clearly stated and correctly used. However, the student misses the connection between mass and weight. The lack of communication in the response shows that the student has not internalized the "big picture" of balanced forces.

The student receives check 10 in part **c.** by identifying a change in the frequency. The response fails to address any other changes and therefore does not receive any additional checks. The total of 7 checks converts to a mark of 5.

Written Response 2

Written Response 2 is to be scored for the knowledge of physics demonstrated (8 marks) and for the effectiveness of the communication (3 marks). Tables follow, setting out the scoring criteria in detail.

The key relationship looked for in the solution is between experimental result and theoretical advancement. Many students are able to list who did what, but putting that knowledge into perspective separates those at the *acceptable standard* from those at the *standard of excellence*.

The task as it appears in the Student Booklet:

Written Response — 11 marks

2. Newton thought light was a stream of particles. Experimental results like those of Foucault, Young, and Poisson have led to the idea that light is a wave. Explain how this evolution occurred. Include experimental results, and explain how these results caused the model to change.

Note: A maximum of 8 marks will be awarded for the physics used to answer this problem. A maximum of 3 marks will be awarded for the effective communication of your response.

General Trends

Students who simply list experiments, even with detailed descriptions of the experimental results, have attempted only half of the full solution. Similarly, students who use a single experiment to support a model have only addressed half the solution.

To move into the three or four region of the content matrix, the response needs to include statements showing the effects of experimental results on the models of light.

Scoring Criteria for Written Response 2

Written Response 2—Scoring Criteria for Communication

Standard	Criteria
3	*The student response* • is complete and well organized, and the explanation of the solution is relevant, appropriate, and clear • describes the strategy in detail and in a logical manner, demonstrating consistency of thought • uses physics vocabulary appropriately, and a precise, explicit relationship exists between the explanation and diagrams • explicitly states the formula, if used • may contain a mathematical error, but this does not hinder the understanding of either the strategy or the solution
2	• is organized, and the attempt to explain the solution is appropriate; however, errors sometimes affect the clarity of the explanation • describes the strategy, but details are generally and/or sometimes lacking, leaving it somewhat open to interpretation • sometimes misuses physics vocabulary; an implicit relationship exists between explanation and diagrams (if used) • may not state the formula, which may, however, be inferred by analyzing the calculations • may contain mathematical errors that can hinder the understanding of either the strategy or the solution
1	• lacks organization, and the attempt to explain all aspects of the problem is not evident; errors affect the clarity of the explanation • describes a strategy that provides little or no detail • often misuses physics vocabulary; a weak relationship exists between the explanation and diagrams (if used) • calculations may appear, but the relationship between the calculations and the solution is unclear • may contain mathematical errors that hinder the understanding of the strategy and/or the solution
0	• is not organized, and there is little or no attempt to explain any aspect of the problem • does not describe a strategy to solve the problem • uses little or no physics vocabulary, and misuses what there is; no relationship exists between the explanation and diagram (if present) • may state a formula that does not contribute toward the solution • is confusing and/or frustrating to the reader • contains very little information
NR	No response is given

Written Response 2—Scoring Criteria for Foundations of Scientific Knowledge

Standard	Criteria
4	*The student response* • is well organized and addresses all major points of the question • explicitly identifies and interrelates relevant scientific, technological, and/or societal concepts • contains descriptions and/or explanations that reflect a **thorough understanding** land logical **consistency** of thought • uses correct diagrams and/or sketches to illustrate descriptions and/or explanations • may contain omissions or inconsistencies, but the understanding of the solution is clear
3	• is organized and addresses most of the major points of the question • identifies and interrelates relevant scientific, technological, and/or societal concepts • contains descriptions and/or explanations that are organized and that reflect a **good understanding** and logical **consistency** of thought • uses correct diagrams and/or sketches to illustrate descriptions and/or explanations • contains at most one major omission or inconsistency
2	• has some organization and addresses some of the major points of the question • implies relevant scientific, technological, and/or societal concepts; interrelationships are weak • shows **some understanding** in the descriptions and/or explanations
1	• addresses some of the major points of the question • shows little understanding • identifies concepts, but shows no interrelationships • superficially describes and/or explains the concepts • shows minimal organizational skills
0	• does not address any of the major points of the question
NR	No response is given

Marking: The marks are arrived at in the following manner:
Take the level of the response from the
Scoring Criteria for Foundations of Scientific Knowledge
and multiply by two; e.g., $4 \times 2 = 8$
Add the score from the
Scoring Criteria for Communication; e.g., $8 + 3 = 11$

Student Example 1

This response would receive a score of 10 out of 11.

Physics 20

Scoring Criteria

Communication **2**	*The student response* • is organized, and the attempt to explain the solution is appropriate; however, errors sometimes affect the clarity of the explanation • describes the strategy, but details are generally and/or sometimes lacking, leaving it somewhat open to interpretation • sometimes misuses physics vocabulary; an implicit relationship exists between explanation and diagrams (if used) • may not state the formula, which may, however, be inferred by analyzing the calculations • may contain mathematical errors that can hinder the understanding of either the strategy or the solution
Content **4**	*The student response* • is well organized and addresses all major points of the question • explicitly identifies and interrelates relevant scientific, technological, and/or societal concepts • contains descriptions and/or explanations that reflect a **thorough understanding** and logical **consistency** of thought • uses correct diagrams and/or sketches to illustrate descriptions and/or explanations • may contain omissions or inconsistencies, but the understanding of the solution is clear

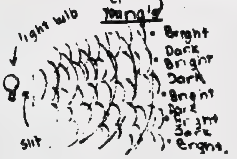
Continued

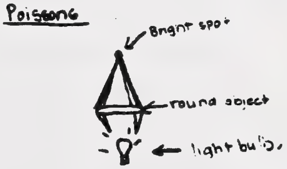
Written Response — 11 marks

2. **Newton thought light was a stream of particles. Experimental results like those of Foucault, Young, and Poisson have led to the idea that light is a wave. Explain how this evolution occurred. Include experimental results, and explain how these results caused the model to change.**

Note: **A maximum of 8 marks will be awarded for the physics used to answer this problem. A maximum of 3 marks will be awarded for the effective communication of your response.**

The evolution of the realization that light was actually a wave came slowly. One experiment was discovered by a man named Young. the experiment called the double slit in which a tiny slit was made into a sheet of paper and placed in front of a light. This effect then produced a bunch of bright and dark spots, proving that there was constructive and destructive interference going on. This was a characteristic of a wave, not a particle.





Simon Poisson then concluded that if light was actually a wave then if he placed a round object infront of a light then the light would diverge around the object and then converge to produce a bright spot in the middle of a white screen. He could not actually prove this. But it was later on proven by a man named Arago.

A man named Augstin Frensel then, (before Poisson) created calculations that only made sense if light were to be a wave. And it was later on concluded that this was such the case.

Commentary

Communication

The student shows good organizational skills in this response. Each of the three scientists is dealt with in complete paragraphs. The student attempts to explain the solution, but the description of Poisson's dot and the incorrect chronological order interferes with the clarity of the explanation. There is a clear relationship between the verbal response and the diagrams. The Young's diagram is somewhat open to interpretation because of all the wave fronts. The student uses physics vocabulary in relating "bright and dark spots" to "constructive and destructive interference."

Content

To address all the points of the solution the student needs to summarize experimental results and show how those results caused the model of light to evolve. In this response, the student demonstrates a thorough understanding by describing the diffraction and interference of light, and by drawing the conclusion, "This was a characteristic of a wave, not a particle." The description of the formation of Poisson's dot is acceptable. The student then refers to the work of Frensel to cement wave nature, thus showing the evolution of the model of light. The response is easily understood. The lack of chronological order is not significant in the content mark.

Student Example 2

This response would receive a score of 9 out of 11.

Physics 20

Scoring Criteria

Communication **3**	*The student response* • is complete and well organized, and the explanation of the solution is relevant, appropriate, and clear • describes the strategy in detail and in a logical manner, demonstrating consistency of thought • uses physics vocabulary appropriately, and a precise, explicit relationship exists between the explanation and diagrams • explicitly states the formula, if used • may contain a mathematical error, but this does not hinder the understanding of either the strategy or the solution
Content **3**	*The student response* • is organized and addresses most of the major points of the question • identifies and interrelates relevant scientific, technological, and/or societal concepts • contains descriptions and/or explanations that are organized and that reflect a **good understanding** and logical **consistency** of thought • uses correct diagrams and/or sketches to illustrate descriptions and/or explanations • contains at most one major omission or inconsistency

Continued

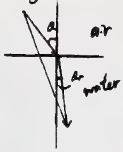
Written Response — 11 marks

2. Newton thought light was a stream of particles. Experimental results like those of Foucault, Young, and Poisson have led to the idea that light is a wave. Explain how this evolution occurred. Include experimental results, and explain how these results caused the model to change.

Note: A maximum of 8 marks will be awarded for the physics used to answer this problem. A maximum of 3 marks will be awarded for the effective communication of your response.

1. Both particles and waves reflect when it hits objects, it cannot determine light is particles or waves.
2. The speed of light is slower in water than in air.

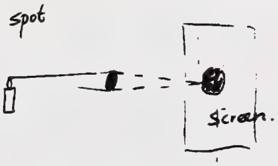
If light is a stream of particles, and the angle of



refraction θ_r is smaller than θ, the speed of the light should be faster in water than in air. Therefore light is a wave

3. The polarization of light.
White light can be polarized because different color of light have different wavelengths. Only waves have wavelengths. There light is a wave.

4. Light spot



If light is particles, it will reflect off the object and the shadow will not have a light spot. But light is a wave, so the shadow has a light spot.

Commentary

Communication
The response is well organized and complete. Each idea is numbered. The student demonstrates consistency in thought through the repeated comparison of wave and particle behaviour in each point. There is a precise and explicit relationship between the diagrams and the explanations through references such as θ_r and θ_s. The student uses physics vocabulary correctly by naming the "angle of refraction."

Content
The response addresses the major points of the question. The student demonstrates a good understanding of the evolution of the theory of light by listing the concepts in chronological order. In identifying reflection as being valid for both models, the student provides a starting point for the evolution. In the conclusion on refraction, the student shows that only the wave model is valid. The student reinforces this model by citing Poisson's dot. By using diagrams, the student supports the explanation. This response was given a 3 rather than a 4 because in point 2, the student indicates the speed of light is faster in water than in air, which is a major error.

Student Example 3

This response would receive a score of 5 out of 11.

Physics 20

Scoring Criteria

Communication **1**	*The student response* • lacks organization, and the attempt to explain all aspects of the problem is not evident; errors affect the clarity of the explanation • describes a strategy that provides little or no detail • often misuses physics vocabulary; a weak relationship exists between the explanation and diagrams (if used) • calculations may appear, but the relationship between the calculations and the solution is unclear • may contain mathematical errors that hinder the understanding of the strategy and/or the solution
Content **2**	*The student response* • has some organization and addresses some of the major points of the question • implies relevant scientific, technological, and/or societal concepts; interrelationships are weak • shows **some understanding** in the descriptions and/or explanations

Continued

Written Response — 11 marks

2. **Newton thought light was a stream of particles. Experimental results like those of Foucault, Young, and Poisson have led to the idea that light is a wave. Explain how this evolution occurred. Include experimental results, and explain how these results caused the model to change.**

Note: **A maximum of 8 marks will be awarded for the physics used to answer this problem. A maximum of 3 marks will be awarded for the effective communication of your response.**

Poisson said that if light was shone on an object, a spot should be found in the center of the object. Poisson never found this spot which proved Newton's theory right. But later, another man found the spot. If light were particles, it would just pass around and through the object because particles don't 'gather' together.

It was Thomas Young's experiment that finally proved light is a wave. When a light was shone through his experiment, called Young's Double Slit experiment, the light came through in a pattern of dark, light, dark light etc. the very center of these spots would be the brightess as most of the light was focused here. The bright spots were formed when a 'crest' met a 'crest' and this only occurs in waves.

Commentary

Communication
The lack of chronological order hinders the organization of this response. The student identifies the contributions of two people, Poisson and Young, in a superficial manner. There is no physics vocabulary used to assist the explanation. Vocabulary that is expected includes interference, constructive or destructive, and diffraction.

Content
The student addresses some of the key ideas by presenting the results of Poisson's and Young's experiments but does not attend to detail in the description. That the connection between the experiments and the evolution of the theory is weak is shown in the concluding sentence— "this only occurs in waves." In the response, the lack of observable interference supports a particle model and then interference "proves" wave nature. This implies, but does not explain, the effects of experimental results to the evolution of the model.

Student Example 4

This response would receive a score of 3 out of 11.

Physics 20

Scoring Criteria

Communication **1**	*The student response* • lacks organization, and the attempt to explain all aspects of the problem is not evident; errors affect the clarity of the explanation • describes a strategy that provides little or no detail • often misuses physics vocabulary; a weak relationship exists between the explanation and diagrams (if used) • calculations may appear, but the relationship between the calculations and the solution is unclear • may contain mathematical errors that hinder the understanding of the strategy and/or the solution
Content **1**	*The student response* • addresses some of the major points of the question • shows little understanding • identifies concepts, but shows no interrelationships • superficially describes and/or explains the concepts • shows minimal organizational skills

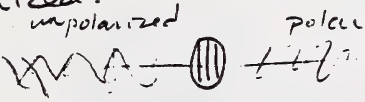
Continued

Written Response — 11 marks

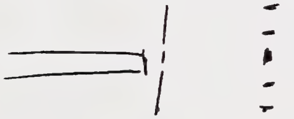
2. **Newton thought light was a stream of particles. Experimental results like those of Foucault, Young, and Poisson have led to the idea that light is a wave. Explain how this evolution occurred. Include experimental results, and explain how these results caused the model to change.**

Note: **A maximum of 8 marks will be awarded for the physics used to answer this problem. A maximum of 3 marks will be awarded for the effective communication of your response.**

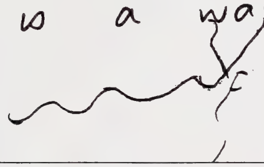
The polarization of light is one way it was proved to be a wave. Particles cannot be polarized.



Diffraction of light also proved that light is a wave since particles cannot bend



Scattering also proves light is a wave



Commentary

Communication
This response shows minimal organization. Each point listed has a diagram.. By not addressing the evolution of the model of light, the student does not address all aspects of the problem. There is no detail in the explanation of diffraction and the relationship between the diagram and description is very weak. The diagram does not illustrate the bending of a wave. Physics vocabulary of interference is absent.

Content
The student addresses part of the question by identifying diffraction. The student demonstrates minimal physics knowledge in the claim that "light is a wave since particles cannot bend." However, this does not address the evolution of the model at all. There are three ideas, but there are no connections among them. In addition, polarization is supportive of either model, and scattering is a natural phenomena and not the result of experimentation. This student shows little understanding of physics or scientific processes.

Performance Tasks

- ***Dart Gun***
- ***Geological Surveys***
- ***Building a Flashlight***
- ***Water Waves***

CLASSROOM
ASSESSMENT
MATERIALS

Scoring Criteria for Performance Tasks

Holistic Scoring Criteria for Procedure

When marking the PROCEDURE, consider how effectively the response uses **physics concepts, knowledge, and skills** to show how the procedure would give data to solve the problem.

Level	Criteria
4	The problem is **thoroughly understood**. An **appropriate** and **practical** procedure is presented in a clear **sequence**. The data to be collected would be **accurate** and would **solve** the problem. Any omissions or inconsistencies do not hinder the communication of the procedure.
3	The problem is **well understood**. An **appropriate** and **practical** procedure is presented, but the data to be collected would be **insufficient** to solve the problem. Any omissions or errors in the sequence affect the validity of the data to be collected.
2	The problem is **understood**. A practical procedure, with major omissions or errors, that could be followed only by someone who knew what was being looked for is presented. The data to be collected may be too **inaccurate** to solve the problem.
1	The problem is **poorly understood**. The procedure is **incomplete** and the method used to obtain the data is **inappropriate**. Sufficient description is provided that the marker can infer that the data, if collected, could have been used to solve the problem.
0	The problem is **not understood**. The procedure, if evident, would generate data that would **not be useful** in solving the problem.

Holistic Scoring Criteria for Observations

When marking OBSERVATIONS, consider how effectively the response **communicates** the outcomes of the procedure.

Level	Criteria
4	The data gathered are **consistent** with the procedure. The observations and results are **complete**. They are **clearly** and **logically recorded**. The observations communicate multiple trials, where appropriate, to solve the problem. Correct scientific conventions of communication are evident in **precision** of measurements and **units**.
3	The data gathered are **mostly consistent** with the procedure. The observations and results are **mostly complete**: they may contain omissions or errors, but the problem is still solvable. Scientific conventions of communication are used.
2	The data gathered **relate** to the procedure. The observations and results are **incomplete**, and it is likely that the problem cannot be solved with these results. The use of scientific conventions of communication is **inconsistently** followed.
1	The data gathered **relate** to the procedure. Scientific conventions of communication are absent.
0	The data gathered are **unrelated** to the procedure or **no observations** are made.

Holistic Scoring Criteria for Analysis

When marking ANALYSIS, consider how effectively the response uses **physics concepts, knowledge, and skills** to use the observations and results to solve the problem.

Level	Criteria
4	The analysis is **well organized** and **thoroughly understood**. The mathematical treatment of the observations and results is **correct**, including formulas, calculations, graphs, significant digits, and units, etc. The data are **accurately** and **completely** analyzed. Minor errors may exist in the analysis.
3	The analysis is **mostly organized** and **mostly understood**. The mathematical treatment of the observations and results is **generally correct**. The data are analyzed, but some errors or inaccuracies exist.
2	The analysis has **some** level of **organization** and shows **some understanding**. The mathematical treatment of the observations and results is only **partially correct**. The calculations may be inaccurate for the observations obtained.
1	The analysis is **disorganized**. The mathematical treatment is **incomplete** and **inaccurate**.
0	No analysis is done.

Holistic Scoring Criteria for the Solution to the Problem

When marking the SOLUTION TO THE PROBLEM, consider how effectively the response **communicates** the solution.

Level	Criteria
4	A **solution** to the problem is given, using appropriate scientific conventions of significant digits and units where appropriate. The solution is **thoroughly supported** by the analysis. The **evaluation** of the solution is **properly** made in terms of the believability of the solution and any errors in the procedure.
3	A **solution** to the problem is given that is **generally supported** by the analysis. The **evaluation** of the solution is **poorly** made.
2	A **solution** to the problem is given that is **generally supported** by the analysis. **Evaluation** of the solution is **ignored**.
1	A **solution** to the problem is given, but is **not supported** by the analysis. **Evaluation** of the solution is **missing**.
0	No solution is given. No evaluation is made.

Practice Task—Dart Gun

The task as it appears in the Student Booklet:

Context

Toy manufacturers must always be safety-conscious when designing toys. This is especially true for toys like dart guns. As a physics consultant, your job is to accurately measure the speed at which the dart leaves the gun.

Problem

Determine as accurately as possible the speed at which the dart **leaves** the gun.

Materials

You may use some or all of the following:

- dart gun
- dart
- metre stick
- stopwatch
- masking tape

Instructions

You have 20–30 minutes to design and use a procedure to solve the problem.

- Describe your *procedure*.

CAUTION: Do not point the dart gun at anyone.

- Communicate your *observations*.
- *Analyze* your results. Include all necessary calculations, graphs, etc., to solve the problem.
- *Solve* the problem and *evaluate* your solution.
- Remember that your work will be scored for *procedure*, *observations*, *analysis*, and *solution to the problem*.

Before leaving this station, put all items of equipment back where you found them. **Leave the station as it was when you arrived.**

General Trends

This task was handled well by students with a strong understanding of projectile motion, namely, that the horizontal motion is considered to be uniform.

In setting the controls, students usually fixed height and angle. When calculating speed students correctly did horizontal distance over time and then found the average of the speeds.

Some difficulties students encounter include a coordination problem in launching the dart and starting the stopwatch simultaneously. A second difficulty is conceptual: students determine the magnitude of the velocity of the dart as it hits the ground. As these students have already found the horizontal speed this error is only likely to penalize the student one mark in each of the analysis and the solution section of the assessment.

An interesting variation had a student controlling the horizontal distance by shooting the dart against a wall.

For a student to receive a four in the solution portion of this task the student is expected to state the determined speed as found in the analysis, make a connection to the real world, and evaluate the numerical solution by identifying sources of error.

Student Example 1

This response would receive a score of 14 out of 16.

Procedure

Scoring Criteria

4

The problem is **thoroughly understood**. An **appropriate** and **practical** procedure is presented in a clear **sequence**. The data to be collected would be **accurate** and would **solve** the problem. Any omissions or inconsistencies do not hinder the communication of the procedure.

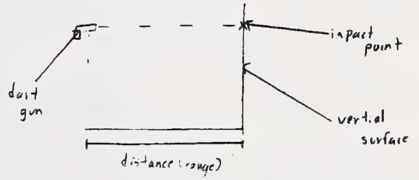
You may find it helpful to identify the important variables before providing your procedure.

Manipulated (independent) variable Velocity of Dart
Responding (dependent) variable Time
Controlled variable(s) Distance, air resistance

Procedure Score __ , ___

1. Assemble all the materials needed.
2. Measure a fixed distance from a vertical surface, and mark the distance with a pencil or tape.
3. Prepare the dart gun, and make several practise trials confirming that the dart can reach the distance. If not, adjust the distance accordingly.
4. When suitable distance is reached, continue the experiment.
5. When firing the gun, it should be parallel to the floor. Use a stop-watch to measure the time interval between release and impact on surface.
6. Proceed with several trials to attain an accurate value of time, and record the information in a table.
7. Once necessary information is obtained, dismantle the apparatus, and begin on calculations.

Diagram



Commentary

The student provides a concise, step-by-step practical procedure in a clear, logical sequence that reflects a thorough understanding of the problem. The student identifies a control of a fixed distance in step 2 and measures time in step 5. In step 6, the student improves the accuracy of the procedure with several trials. The student also provides a diagram to aid the explanation of the procedure.

Continued

Observations

Scoring Criteria

3

The data gathered are **mostly consistent** with the procedure. The observations and results are **mostly complete**: they may contain omissions or errors, but the problem is still solvable. Scientific conventions of communication are used.

Observations

Score _._ ___

Trial Number	Distance (m)	Time (s)
1	1.00m	0.22
2	1.00m	0.25
3	1.00m	0.22

Commentary

The student provides data that are consistent with the procedure. The reason that this response receives a 3 and not a 4 is because of the very short distance of 1.00 m selected. The responding travel time of the dart is too short to be measured by a hand-held stopwatch. Although this is a major error that prevents an accurate solution to the problem, the problem is still solvable. Proper conventions of units and precision are used.

Continued

Analysis

Scoring Criteria

3

The analysis is **mostly organized** and **mostly understood**. The mathematical treatment of the observations and results is **generally correct**. The data are analyzed but some errors or inaccuracies exist.

Analysis

$$\Delta t_{av} = \Delta t_1 + \Delta t_2 + \Delta t_3 / 3$$
$$= (0.22 + 0.25 + 0.22)s / 3$$
$$= 0.69 s / 3$$
$$= 0.23 s$$

$$V_{av} = \frac{\Delta \vec{d}}{\Delta t_{av}}$$
$$= \frac{+1.00 m}{0.23 s}$$
$$= 4.35 m/s$$

$$\Delta d = v_i t + \tfrac{1}{2} \vec{a} t^2$$

$$\frac{2d}{\Delta t} = \vec{v}_i$$
$$\frac{2(1.00 m)}{0.23} =$$
$$\vec{v}_i = 8.70 m/s$$

Commentary

The student lists the formula, uses an appropriate averaging technique, and states the correct units. The student receives a 3 instead of a 4 for analysis because the answer for average velocity of 4.35 m/s uses inappropriate significant digits. In assigning a mark, the work at the bottom of the page is ignored because the student states a solution of 4.35 m/s not 8.70 m/s in the solution to the problem.

Continued

Solution

Scoring Criteria

4

A **solution** to the problem is given, using appropriate scientific conventions of significant digits and units where appropriate. The solution is **thoroughly supported** by the analysis. The **evaluation** of the solution is **properly** made in terms of the believability of the solution and any errors in the procedure.

Recall this information as you provide your solution to the problem.

Context

Toy manufacturers must always be safety-conscious when designing toys. This is especially true for toys like dart guns. As a physics consultant, your job is to accurately measure the speed at which the dart leaves the gun.

Problem

Determine as accurately as possible the speed at which the dart **leaves** the gun.

Solution to the Problem Score ______

According to our results in the experiment, the speed of the dart, as accurately as possible, worked out to about 4.35 m/s. While this result is what our calculations provided us, our information could have been faulty due to human inconsistency and errors in measurements. A dart moving at such a speed offers very little hazard to anyone if fired at them. The resulting impact would be approximate to a light slap, if even that much. The mass of the dart, and material it is constructed from, provide sufficient padding, and minimal danger.

Commentary

The student provides a solution that is supported by the analysis. The evaluation is present and includes possible sources of error and a description of the connection between dart speed and safety.

Summary Comment

The student's work is well organized, concise, and very easy to read and understand. It is evident that the student understands the problem and has designed a practical experiment that can be performed in the classroom. Formulas, substitution, and correct conventional procedures are always listed in the student's responses. The student also attempts to apply physics to the real world by relating the force of the dart to a slap in the face.

Student Example 2

This response would receive a score of 12 out of 16.

Procedure

Scoring Criteria

3

The problem is **well understood**. An **appropriate** and **practical** procedure is presented, but the data to be collected would be **insufficient** to solve the problem. Any omissions or errors in the sequence affect the validity of the data to be collected.

You may find it helpful to identify the important variables before providing your procedure.

Manipulated (independent) variable height of arrow's release

Responding (dependent) variable distance arrow travels

Controlled variable(s) force causing arrow to be shot

Procedure **Score** ______

I. Establish a point of reference (starting point) Mark this spot with line of masking tape. This is where dart will be shot from.

II From masking tape line, fire dart from a consistent height (approx. 1.5m). Make sure to pull elastic sling (force) all the way out to ensure consistent force. Fire dart parallel to the ground

III. Measure time of dart's release to time of hitting The ground. That is, start stopwatch just as dart is shot and stop the stopwatch just as dart hits ground.

IV. Measure distance from dart's release to dart's point of stoppage (when it hits ground.) Place masking tape at landing point & ma

V. Use observations and complete all necessory calculations

Commentary

The procedure is presented in a practical sequence that can be easily understood. The student identifies two controls of a constant height of 1.5 m from which the dart is fired and a constant force that is applied to the dart gun. The two variables of time and distance to be measured are indicated in steps 3 and 4. The student loses one mark because multiple trials have not been indicated. Multiple trials are necessary for sufficient data collection.

Continued

Observations

Scoring Criteria

3

The data gathered are **mostly consistent** with the procedure. The observations and results are **mostly complete**: they may contain omissions or errors, but the problem is still solvable. Scientific conventions of communication are used.

Observations **Score ___**

Trial Number	Time (s)	Distance (m)
1	1.17	9.623
2	0.87	8.216
3	0.82	8.183

Commentary

Although the procedure does not specify multiple trials, the student records data for multiple trials with the appropriate units for time and distance. The student receives a 3 instead of a 4 because of an error in precision, too many decimals, in recording distance.

Continued

Analysis

Scoring Criteria

3

The analysis is **mostly organized** and **mostly understood**. The mathematical treatment of the observations and results is **generally correct**. The data are analyzed, but some errors or inaccuracies exist.

Analysis

I Find V_i

Trial One:

$$V_{i_1} = \frac{d}{T}$$

$$= \frac{9.623\,m}{1.17\,s}$$

$$V_{i_1} = 8.225\,\frac{m}{s}$$

Trial Two:

$$V_{i_2} = \frac{d}{T}$$

$$= \frac{8.216\,m}{0.87\,s}$$

$$V_{i_2} = 9.444\,\frac{m}{s}$$

Trial Three:

$$V_{i_3} = \frac{d}{T}$$

$$= \frac{8.183\,m}{0.82\,s}$$

$$V_{i_3} = 9.979\,\frac{m}{s}$$

II Find Average V_i

$$V_i(ave) = \frac{V_{i_1} + V_{i_2} + V_{i_3}}{3}$$

$$= \frac{8.224786\,\frac{m}{s} + 9.443678\,\frac{m}{s} + 9.979268\,\frac{m}{s}}{3}$$

$$V_{i(ave)} = 9.215910926\,\frac{m}{s}$$

Commentary

The student analyzes the data in a well-organized manner by providing a formula, correct calculations, an appropriate averaging technique, and correct units. The student is awarded a 3 instead of a 4 because the scientific convention of significant digits is applied incorrectly in the answer of 9.215910926 m/s.

Continued

Solution

Scoring Criteria

3

A **solution** to the problem is given that is **generally supported** by the analysis. The **evaluation** of the solution is **poorly** made.

Recall this information as you provide your solution to the problem.

Context

Toy manufacturers must always be safety-conscious when designing toys. This is especially true for toys like dart guns. As a physics consultant, your job is to accurately measure the speed at which the dart leaves the gun.

Problem

Determine as accurately as possible the speed at which the dart leaves the gun.

Solution to the Problem Score ______

The dart leaves the gun at a speed of 9.216 $\frac{m}{s}$.

Errors in the experiment causing inaccuracy may have been that the:

(1) height of dart's release might be inconsistent

(2) method of time measure allowed for human error Watch may not have started and stopped at dart's release and stoppage respectively.

(3) distance was measured using a metre stick and may have allowed several errors as stick was moved for every metre of flight.

(4) area in which dart was shot had fluctuating drafts and likely inconsistent air pressure.

Commentary

The student provides a solution that is supported by the analysis. A list of four sources of error is provided to indicate why the final solution may not be entirely valid. The evaluation of the solution is weak because the speed of the dart has not been related to real-life speeds in terms of believability.

Student Example 3

This response would receive a score of 9 out of 16.

Procedure

Scoring Criteria

2

The problem is **understood**. A practical procedure, with major omissions or errors, that could be followed only by someone who knew what was being looked for is presented. The data to be collected may be too **inaccurate** to solve the problem.

You may find it helpful to identify the important variables before providing your procedure.

Manipulated (independent) variable Distance (m)
Responding (dependent) variable time (s)
Controlled variable(s) velocity (speed) m/s

Procedure Score ______

① Take a large scale
(ii) Release the dart gun from a ~~fixed~~ different distence.
(iii) ~~Measure the distance~~ start timing
(iv) and Measure the distance

CAUTION: DO NOT POINT THE GUN AT ANYONE.

Commentary

The student understands that measuring distance and time are needed to solve the problem. In step III, the student indicates that the trial is timed, and a distance is measured in step IV. The major omissions of when to stop timing and which distance (vertical or horizontal) to measure make this a procedure that could only be followed by someone who knows what is being looked for as a final result. There is no indication of multiple trials, and there is no indication of appropriate controls.

Continued

Observations

Scoring Criteria

2

The data gathered **relate** to the procedure. The observations and results are **incomplete**, and it is likely that the problem cannot be solved with these results. The use of scientific conventions of communication is **inconsistently** followed.

Observations Score ______

Trial Number	Distance (m)	Time (m)
1	30m	1.19s
2	40m	1.35s
3	50m	1.22s

~~Speed of the dart gun = velocity / time taken~~

$\therefore$ velocity = $\frac{d}{t}$

$= \frac{\cancel{40m}}{1.\cancel{35}s}$ $\frac{30m}{1.19s}$

= 25 m/s

$\therefore$ the velocity of the dart gun is 25 m/s

Commentary

The student shows multiple trials. Distance and time data are indicated. The student has unrealistic travelling distances of 30 m, 40 m, and 50 m. The student's units for time are inconsistent (minutes and seconds).

Continued

Analysis

Scoring Criteria	*Analysis* Score ______
3 The analysis is **mostly organized** and **mostly understood**. The mathematical treatment of the observations and results is **generally correct**. The data are analyzed, but some errors or inaccuracies exist.	

Commentary

The analysis appears both under observations and the solution to problem. The velocity formula and calculation of 25 m/s appears under observations. The rest of the calculations appear under solution to the problem. The velocities are consistent with the data for each trial. The student has used correct units and significant digits in all calculations. The student does not show a form of averaging to determine the average speed of the projectile.

Continued

Solution

Scoring Criteria

2

A **solution** to the problem is given that is **generally supported** by the analysis. **Evaluation** of the solution is **ignored**.

Recall this information as you provide your solution to the problem.

Context

Toy manufacturers must always be safety-conscious when designing toys. This is especially true for toys like dart guns. As a physics consultant, your job is to accurately measure the speed at which the dart leaves the gun.

Problem

Determine as accurately as possible the speed at which the dart leaves the gun.

Solution to the Problem

Score ______

Velocity = d/t . . . ① Trial ①

$= \frac{30\text{m}}{1.19\text{s}}$

= 25 m/s

Velocity = d/t . . . (II) Trial (II)

$= \frac{40\text{m}}{1.35\text{s}}$

= 30 m/s

Velocity = d/t

$= \frac{50\text{m}}{1.22\text{s}}$

= 41 m/s

∴ 32 m/s is the average speed at which the dart leaves the gun.

Commentary

The solution starts where the therefore symbol (∴) appears. The student's answer is consistent with data from the analysis. The student uses correct significant digits and units in the answer. The student does not describe any sources of error and does not relate the solution to the context of the question, thus the evaluation of the solution is ignored.

Summary Comment

This student can generate distance/time data and use it to calculate speed quantities required by the task. The student has difficulty extending procedures to account for variables in problem solving. The student did not make connections between the speed of the projectile and its impact on children and society in general. It is also difficult for the student to identify sources of error in the procedure performed in the task.

Student Example 4

This response would receive a score of 5 out of 16.

Procedure

Scoring Criteria

1

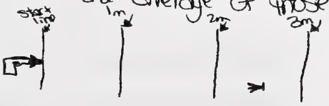
The problem is **poorly understood**. The procedure is **incomplete** and the method used to obtain the data is **inappropriate**. Sufficient description is provided that the marker can infer that the data, if collected, could have been used to solve the problem.

You may find it helpful to identify the important variables before providing your procedure.

Manipulated (independent) variable ______ pulled off the [illegible]
Responding (dependent) variable distance flown
Controlled variable(s) ~~ela~~ elasticity

Procedure Score ______

Mark out 3 m on the floor with tape, every metre. Place the gun sideways on the ground with the tip of the dart on the line. Pull the trigger back and fire, letting the dart continue until it stops. Repeat 2 more times, recording the distances the dart travels. Take the average of those distances.



Commentary

The student understands that a distance measurement is required to solve the problem, but shows poor understanding because no time measurements are made and the effects of friction would result in decelerated, not uniform, motion. If the student had fired the gun at any fixed height above the floor and measured time, then this procedure would generate data that could be used to solve the problem.

Continued

Observations

Scoring Criteria

2

The data gathered **relate** to the procedure. The observations and results are **incomplete**, and it is likely that the problem cannot be solved with these results. The use of scientific conventions of communication is **inconsistently** followed.

Observations

Score ______

Trial Number	distance flown(m)	
1	2.11	
2	2.31	
3	2.59	
Average	2.33	

Commentary

The data clearly relate to the distance measurements from the procedure. The problem of finding the speed cannot be accomplished with these observations. Although scientific conventions of units, precision, table headings, are consistently followed, this remains a 2 because the results are incomplete.

Continued

Analysis

Scoring Criteria

1

The analysis is **disorganized**. The mathematical treatment is **incomplete** and **inaccurate**.

Analysis

Score ______

Commentary

The analysis is recorded under the observations. The student correctly calculates the average distance; however, the absence of formulas makes the mathematical treatment incomplete.

Solution

Scoring Criteria

1

A **solution** to the problem is given, but is **not supported** by the analysis. **Evaluation** of the solution is **missing**.

Recall this information as you provide your solution to the problem.

Context

Toy manufacturers must always be safety-conscious when designing toys. This is especially true for toys like dart guns. As a physics consultant, your job is to accurately measure the speed at which the dart leaves the gun.

Problem

Determine as accurately as possible the speed at which the dart leaves the gun.

Solution to the Problem Score ______

The darts only move forward a little bit. [illegible]. I tried to use a stopwatch as part of the experiment, but because the darts go such a little distance, [illegible] they don't take very much time. the darts are soft, so they flip around quite abit because the backend is plastic.

Commentary

This student's experimental design is such that the student is unable to solve the problem. This solution to the problem receives one mark because the student identifies sources of error that affected the activity.

Performance Task 1—Geological Survey

The task as it appears in the Student Booklet:

Context

Geo-Co of Alberta is a small company involved in locating natural resources in Alberta. Although it uses ultrasound to pinpoint mineral and oil deposits, the ultrasound machinery is expensive to transport and maintain. As a physics consultant, you tell the board of Geo-Co that you know of a less expensive way to get the general locations of mineral and oil deposits, which they can then pinpoint with the ultrasound equipment. You explain to them that mineral deposits cause an increase in the gravitational field while an oil deposit causes a decrease. The board of Geo-Co approves this method for the generalized locating of natural resources.

Problem

Based on the gravitational field intensity, determine what the ultrasound machinery would show if Geo-Co brought it to where you are right now.

Materials

You may use some or all of the following.

- string
- scissors
- spring
- ruler
- stopwatch
- graph paper
- set of masses
- 100 ml burette
- burette stand
- funnel
- beaker
- water
- tin pie-plate

Instructions

You have 20–30 minutes to design and use a procedure to solve the problem.

- Describe your *procedure*.

- Communicate your *observations*.

- *Analyze* your results. Include all necessary calculations, graphs, etc., to solve the problem.

- *Solve* the problem and *evaluate* your solution.

- Remember that your work will be scored for *procedure*, *observations*, *analysis*, and *solution to the problem*.

Before leaving this station, put all items of equipment back where you found them. **Leave the station as it was when you arrived.**

General Trends

This task was handled well by all students. Often the range of equipment provided did not distract the student. Most students recognized that a pendulum is an easy way to determine gravitational field intensity.

To receive a four in the solution to the problem the student response is expected to include a statement of the gravitational field intensity determined, a comparison to $a_g = 9.81\ \text{m/s}^2$ and a comment identifying mineral or oil deposits. In this task, as well as in *Building a Flashlight*, error descriptions are not necessary because the student is being asked to make a supported judgement based on experimental results.

Minor changes have been made to the problem statement in response to comments from the pilot teachers.

Student Example 1

This response would receive a score of 14 out of 16.

Procedure

Scoring Criteria

4

The problem is **thoroughly understood**. An **appropriate** and **practical** procedure is presented in a clear **sequence**. The data to be collected would be **accurate** and would **solve** the problem. Any omissions or inconsistencies do not hinder the communication of the procedure.

You may find it helpful to identify the important variables before providing your procedure.

Manipulated (independent) variable length of string (r value)
Responding (dependent) variable g force
Controlled variable(s) mass - 20g

Procedure Score ______

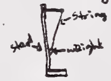
1) Get string, scissors, mass (20g), stand, stop watch + meter stick

2) Tie one end of the string to the top of the stand and tie the 20g mass to the other end so that it hangs high enough that it won't hit the counter top.

3) Measure the length of the string between the weight and the stand top.

4) Pull the weight back so it is touching the stand

eg.



5) Take the stop watch. Time how long it takes, from the time you release the weight until it comes back to it's starting position.

6) Record the time and Use the formula $T=2\pi\sqrt{L/g}$ where T= the time and L= the length of the string. Determine the value of g. Do three trials and record the g values. Then find the average g value.

Commentary

The student thoroughly understands the problem and presents an appropriate and practical procedure—the use of a pendulum. The student's procedure is clear and concise. In step 5, the student measures one period of the pendulum, and in step 6, the repetition addresses the accuracy of the observations.

Continued

Observations

Scoring Criteria

4

The data gathered are **consistent** with the procedure. The observations and results are **complete**. They are **clearly** and **logically recorded**. The observations communicate multiple trials, where appropriate, to solve the problem. Correct scientific conventions of communication are evident in **precision** of measurements and **units**.

Observations

Score ______

string length is 31cm.

Trial Number	Time (s)	g value
1	1.08	10.5
2	1.02	11.8
3	1.01	

#1) $T = 2\pi\sqrt{l/g}$

$1.08 = 2\pi\sqrt{.31/g}$

$0.172)^2 = (\sqrt{.31/g})^2$

$0.0295 = .31/g$

$g = 10.5$

#2) $T = 2\pi\sqrt{l/g}$

$1.02 = 2\pi\sqrt{.31/g}$

$(0.162)^2 = (\sqrt{.31/g})^2$

$0.0262 = .31/g$

$11.8 = g$

#3) $T = 2\pi\sqrt{l/g}$

$1.01 = 2\pi\sqrt{.31/g}$

$(0.161)^2 = (\sqrt{.31/g})^2$

$0.0258 = .31/g$

$g = 12.0$

10.5
11.8
12.0
34.5

$34.5 \div 3 = 11.4$

$g = 11.4\ m/s^2$

Commentary

The student logically and clearly organizes the data in a labelled chart. The pendulum length is recorded beside the observation chart. Correct scientific conventions in the precision of the measurements and the units are present. The calculations present and the “g value” column are part of the analysis and will be marked when the analysis is evaluated.

Continued

Analysis

Scoring Criteria	
3 The analysis is **mostly organized** and **mostly understood**. The mathematical treatment of the observations and results is **generally correct**. The data are analyzed, but some errors or inaccuracies exist.	*Analysis* Score _____ Sorry, I did this on the observations page.

Commentary

The analysis, as done under the observation chart, is well organized. The student states and uses the formula for calculating the gravitational field intensity. However, the averaging method is incomplete because of the missing formula.

Continued

Solution

Scoring Criteria

3

A **solution** to the problem is given that is **generally supported** by the analysis. The **evaluation** of the solution is **poorly** made.

Recall this information as you provide your solution to the problem.

Context

Geo-Co of Alberta is a small company involved in locating natural resources in Alberta. Although it uses ultrasound to pinpoint mineral and oil deposits, the ultrasound machinery is expensive to transport and maintain. As a physics consultant, you tell the board of Geo-Co that you know of a less expensive way to get the general locations of mineral and oil deposits, which they can then pinpoint with the ultrasound equipment. You explain to them that mineral deposits cause an increase in the gravitational field while an oil deposit causes a decrease. The board of Geo-Co approves this method for the generalized locating of natural resources.

Problem

Determine what the ultrasound machinery would show if Geo-Co brought it to where you are right now.

Solution to the Problem Score ______

The g value is 11.4 m/s² so the ultrasound machinery would find that there are mineral deposits here.

Commentary

The student provides a solution to the problem supported by the analysis. The evaluation of the solution is incomplete because the comparison of 11.4 m/s^2 to the accepted value of g is not made. However, the student draws the logical conclusion that mineral deposits are present. The solution to the problem does not need to address sources of error because the student is asked to make a generalization rather than provide a numerical value.

Summary Comment

The student clearly understands the problem and is able to design an appropriate and practical experiment. The student demonstrates knowledge of physics and scientific skills. This student is confident in applying physics and drawing conclusions that relate to the real world.

Student Example 2

This response would receive a score of 12 out of 16.

Procedure

Scoring Criteria

3

The problem is **well understood**. An **appropriate** and **practical** procedure is presented, but the data to be collected would be **insufficient** to solve the problem. Any omissions or errors in the sequence affect the validity of the data to be collected.

You may find it helpful to identify the important variables before providing your procedure.

Manipulated (independent) variable length of String

Responding (dependent) variable The time it takes for 1 swing

Controlled variable(s) Timer, mass, height pendulum's dropped at.

Procedure

Score ______

① Tie a mass to the end of a pendulum

② Record the time it takes to complete one swing. (T)

③ Do 3 time trials and take the averge time.

Commentary

The student shows an understanding of the problem by identifying the use of a pendulum. In step 3, the student addresses the validity of the data by indicating multiple trials. The data is insufficient to solve the problem because the length of the pendulum is not measured.

Continued

Observations

Scoring Criteria

3

The data gathered are **mostly consistent** with the procedure. The observations and results are **mostly complete**: they may contain omissions or errors, but the problem is still solvable. Scientific conventions of communication are used.

Observations

Score ______

weight = 100grams
*doesn't

Trial Number	length	Tine (s)
1	1.21	2.16
2	1.21	2.03
3	1.21	1.94

Average time = 2.04 s

Commentary

The data presented in the data chart is consistent with the procedure. The student indicates that the pendulum length is fixed at 1.21 units. The student is awarded a 3 instead of a 4 because correct scientific convention is not used. The units for the length of the pendulum are not provided.

Continued

Analysis

Scoring Criteria

2

The analysis has **some** level of **organization** and shows **some understanding**. The mathematical treatment of the observations and results is only **partially correct**. The calculations may be inaccurate for the observations obtained.

Analysis **Score** ______

$$T^2 = 2\pi^2\sqrt{\frac{l}{g}} \qquad \frac{T^2}{4\pi^2 l} = \frac{1}{g} \qquad \frac{4\pi^2 l}{T^2} = \frac{g}{1}$$

$$g = \frac{4\pi^2 l}{T^2}$$

$$g = \frac{4(3.14)^2(1.21m)}{2.04s^2} = \boxed{11.47 m/s^2}$$

* From previous knowledge I know the gravatational Field should be around 9.81 m/s²

Commentary

The student identifies the equation needed to solve for acceleration due to gravity and makes the appropriate calculation. Although the average time is stated in the observation chart, the student has not shown the appropriate averaging technique. The student states too many significant digits in the final answer and thus is awarded a 2 instead of a 3.

Continued

Solution

Scoring Criteria

4

A **solution** to the problem is given, using appropriate scientific conventions of significant digits and units where appropriate. The solution is **thoroughly supported** by the analysis. The **evaluation** of the solution is **properly** made in terms of the believability of the solution and any errors in the procedure.

Recall this information as you provide your solution to the problem.

Context

Geo-Co of Alberta is a small company involved in locating natural resources in Alberta. Although it uses ultrasound to pinpoint mineral and oil deposits, the ultrasound machinery is expensive to transport and maintain. As a physics consultant, you tell the board of Geo-Co that you know of a less expensive way to get the general locations of mineral and oil deposits, which they can then pinpoint with the ultrasound equipment. You explain to them that mineral deposits cause an increase in the gravitational field while an oil deposit causes a decrease. The board of Geo-Co approves this method for the generalized locating of natural resources.

Problem

Determine what the ultrasound machinery would show if Geo-Co brought it to where you are right now.

Solution to the Problem Score ______

IF the surveyers came here they would Probably Find large mineral deposits Since the gravitational Field has been increased by $1.66 m/s^2$. I Know that it Should be $9.81 m/s^2$ So we must be Surrounded by a lot of minerals.

Commentary

The student provides a solution that is consistent with the analysis and compares the experimental value for the acceleration due to gravity with the accepted value. The student indicates specifically that because the obtained acceleration due to gravity is greater than the accepted value by $1.66\ m/s^2$, the deposit beneath would contain minerals. Since the student is asked to provide a non-numeric solution, it is unnecessary to address sources of error.

Student Example 3

This response would receive a score of 6 out of 16.

Procedure

Scoring Criteria

1

The problem is **poorly understood**. The procedure is **incomplete** and the method used to obtain the data is **inappropriate**. Sufficient description is provided that the marker can infer that the data, if collected, could have been used to solve the problem.

You may find it helpful to identify the important variables before providing your procedure.

Manipulated (independent) variable ________________

Responding (dependent) variable ________________

Controlled variable(s) ________________________

Procedure **Score** _____

1 Create a pendulum using the string and a mass.

2 Use the formula $T = 2\pi\sqrt{\frac{l}{g}}$ to find the force of gravity

Commentary

The student recognizes that a pendulum can be used to determine the g value. The procedure is incomplete and all information about the pendulum must be inferred. The student does not state the need for multiple trials, controlling variables, measuring pendulum length, or determining period. The student also shows confusion between the gravitational field intensity, g, and the force of gravity, F_g.

Continued

Observations

Scoring Criteria

3

The data gathered are **mostly consistent** with the procedure. The observations and results are **mostly complete**: they may contain omissions or errors, but the problem is still solvable. Scientific conventions of communication are used.

Observations

Score ___

Trial Number	T, period			length of string	mass of weight
1	1.5s	1.43s	1.41s	51 cm	50
2	1.41	1.35	1.33	51 cm	100
3	1.37	1.41	1.31	51 cm	150

average period 1.395

Commentary

The student provides data that are consistent with what is implied in the procedure. Multiple trial data are provided. The student provides all necessary units (mass is not required) but has inconsistencies in the precision of the time observations.

Continued

Analysis

Scoring Criteria

1

The analysis is **disorganized**. The mathematical treatment is **incomplete** and **inaccurate**.

Analysis **Score** ______

$$T = 2\pi\sqrt{\frac{1}{g}} \qquad g = 10.0\ \mathrm{m/s^2}$$

$$T^2 = 2\pi^2 \frac{1}{g}$$

$$\frac{T^2}{2\pi^2} = \frac{1}{g}$$

$$\frac{2\pi^2 \cdot 1}{T^2} = g$$

$$\frac{T}{2\pi} = \sqrt{\frac{1}{g}}$$

$$\left(\frac{T}{2\pi}\right)^2 = \frac{1}{g}$$

Commentary

The student correctly states the average period in the observation chart but does not show the averaging technique used. In the analysis, the student states a valid formula but makes errors in the algebraic manipulation and shows no substitution of values. The stated solution, 10.0 $\mathrm{m/s^2}$, is inconsistent with the data collected, which yields 20.3 $\mathrm{m/s^2}$.

Continued

Solution

Scoring Criteria

1

A **solution** to the problem is given, but is **not supported** by the analysis. **Evaluation** of the solution is **missing**.

Recall this information as you provide your solution to the problem.

Context

Geo-Co of Alberta is a small company involved in locating natural resources in Alberta. Although it uses ultrasound to pinpoint mineral and oil deposits, the ultrasound machinery is expensive to transport and maintain. As a physics consultant, you tell the board of Geo-Co that you know of a less expensive way to get the general locations of mineral and oil deposits, which they can then pinpoint with the ultrasound equipment. You explain to them that mineral deposits cause an increase in the gravitational field while an oil deposit causes a decrease. The board of Geo-Co approves this method for the generalized locating of natural resources.

Problem

Determine what the ultrasound machinery would show if Geo-Co brought it to where you are right now.

Solution to the Problem **Score ____ __**

The problem did not work well due to the lack of proper time, explanation and materials. The answer came out to g = 10.0. This, however, seems to have no bearing to any ultrasound machine?

Commentary

The student provides an answer that relates to the analysis but that lacks units and support. The student does not make the connection between the higher g value and the possibility of mineral deposits.

Performance Task 2—Building a Flashlight

The task as it appears in the Student Booklet:

Context

You are looking for a part-time job and have applied at Bright Lights, a flashlight manufacturing company. As part of the interview for the job, the president of the company tells you that concave mirrors are used to make flashlights. Then she hands you a concave mirror and asks if it would be a good mirror for a flashlight. Your chances for the job will depend upon your answer.

Problem

Determine quantitatively whether this mirror will make a good flashlight.

Materials

You may use some or all of the following:

- concave mirror
- ruler
- light bulb (small) & energy source, or candle & matches
- cardboard sheet
- 3 pushpins
- metre stick
- plasticene

Instructions

You have 20–30 minutes to design and use a procedure to solve the problem.

- Describe your *procedure*.

- Communicate your *observations*.

- *Analyze* your results. Include all necessary calculations, graphs, etc., to solve the problem.

- *Solve* the problem and *evaluate* your solution.

- Remember that your work will be scored for *procedure*, *observations*, *analysis*, and *solution to the problem*.

Before leaving this station, put all items of equipment back where you found them. **Leave the station as it was when you arrived.**

General Trends

This task was handled well by students at all levels if optics had been covered in the course work.

The biggest potential pitfall is in the analysis section of this task, in the averaging techniques students choose. The student who places the light source at three different locations ($d_{0_1}, d_{0_2}, d_{0_3}$) and measures the corresponding locations of the clearest reflection ($d_{i_1}, d_{i_2}, d_{i_3}$) must determine a focal length for each pair (f_1, f_2, f_3) and then average the focal lengths ($f_{ave} = f_1 + f_2 + f_3 /3$). A common error is to find the average of the object location, the image location, and then do a single focal length calculation. This is unacceptable. The formula relating d_0, d_i, and f is $\frac{1}{f} = \frac{1}{d_0} + \frac{1}{d_i}$. Because the variables are not directly proportional, and because a graph of d_i versus d_0 is non-linear, the valid way of calculating an average focal length is to calculate an experimetal result for each trial and then average the results. However, if the student controls the object distance and makes several measurements of the image distance, a single focal length calculation using the averaged image distance would be valid.

An interesting variation is the non-mathematical approach. A student may choose to find the focal length by moving the light source along the axis of the mirror. Since light at the focal point is reflected back parallel to the axis of the mirror, the image on a screen far away will be clearest when the object is exactly at the focal point. The student who locates this position, and then measures the focal point may receive full marks throughout.

To receive a score of four in the solution section the student needs to state the focal length determined and needs to relate that to the size of the resulting flashlight. For example, in real world terms, a bulb at a 7 cm focal length makes a flashlight that is as long as your forearm. That is too big. This mirror is no good. Error comments may or may not be necessary depending on the experimental design.

Student Example 1

This response would receive a score of 13 out of 16.

Procedure

Scoring Criteria

4

The problem is **thoroughly understood**. An **appropriate** and **practical** procedure is presented in a clear **sequence**. The data to be collected would be **accurate** and would **solve** the problem. Any omissions or inconsistencies do not hinder the communication of the procedure.

You may find it helpful to identify the important variables before providing your procedure.

Manipulated (independent) variable Object displacement
Responding (dependent) variable image displacement.
Controlled variable(s) Focal length

Procedure Score ______

(1) Gather all materials needed.
(2) Compleat headings on the chart. Title them Object Displacement & image displacement.
(3) Prop-up a piece of card board on your table.
(4) Place your concave mirror in front of the cardboard.
(5) Place a lit candle in between the cardboard & mirror.
(6) Ajust the candle untill the image on the cardboard is clear and sharp!
(7) measure the distance it is between the concave mirror and your candle. Place data in chart
(8) measure distance of the image from the concave mirror.
(9) Repeat steps (4) to (8) untill all trials are over.

NOTE move around the mirror to get diffrent measurements for more acurate results.

(10) Calculate the principle focus.

Commentary

The student shows a thorough understanding of the problem by providing a practical step-by-step procedure. The measurements of the object distance and image distance are clearly indicated in steps 7 and 8. The accuracy of the data is improved by the multiple trials.

Continued

Observations

Scoring Criteria

3

The data gathered are **mostly consistent** with the procedure. The observations and results are **mostly complete**: they may contain omissions or errors, but the problem is still solvable. Scientific conventions of communication are used.

Observations **Score** __ ___

Trial Number	Object Displacement	Image Displacement
1	16 cm	34.5 cm
2	19.3 cm	26 cm
3	14.8 cm	38.3

(1) Real
(2) $D_o < D_i$
(3) $O_h < I_h$
(4) Inverted.

The image that was projected was real and Inverted. The object Distance was closer to the mirror that the Image distance. The object height was smaller than the Image height.

Commentary

The student presents the data clearly and logically in the form of a data chart. The student receives a 3 instead of a 4 because of errors in precision in both columns of the table—16 cm and 26 cm—and for missing the unit on 38.3.

Continued

Analysis

Scoring Criteria

3

The analysis is **mostly organized** and **mostly understood**. The mathematical treatment of the observations and results is **generally correct**. The data are analyzed, but some errors or inaccuracies exist.

Analysis Score ____

Trial 1:

$$\frac{1}{f} = \frac{1}{D_o} + \frac{1}{D_i}$$

$$\frac{1}{f} = \frac{1}{16\text{cm}} + \frac{1}{34.5\text{cm}}$$

$$\frac{1}{f} = \frac{2}{50.5\text{ cm}}$$

$$f = 25.25\text{ cm}$$

Trial 2:

$$\frac{1}{f} = \frac{1}{D_o} + \frac{1}{D_i}$$

$$\frac{1}{f} = \frac{1}{19.3\text{cm}} + \frac{1}{26\text{cm}}$$

$$\frac{1}{f} = \frac{2}{45.3\text{cm}}$$

$$f = 22.65\text{cm}$$

Trial 3:

$$\frac{1}{f} = \frac{1}{D_o} + \frac{1}{D_i}$$

$$\frac{1}{f} = \frac{1}{14.8} + \frac{1}{38.3.}$$

$$\frac{1}{f} = \frac{2}{53.1\text{cm}}$$

$$f = 26.55\text{cm}.$$

$$f_{\text{average}} = \frac{\text{Trial}_1 + \text{Trial}_2 + \text{Trial}_3}{\#\text{of Trials}}$$

$$f_{\text{ave}} = \frac{25.25\text{cm} + 22.65\text{cm} + 26.55\text{cm}}{3}$$

$$f_{\text{ave}} = 24.8\text{ cm}$$

Commentary

The analysis is well organized and contains an appropriate mathematical treatment. The student has an incorrect number of significant digits in the final answer of 24.8 cm. From the observations, this answer should have only two significant digits. The student is not being penalized twice as a precision error in the observations and significant digit error in a calculation are two separate skills.

Continued

Solution

Scoring Criteria

3

A **solution** to the problem is given, that is **generally supported** by the analysis. The **evaluation** of the solution is **poorly** made.

Recall this information as you provide your solution to the problem.

Context

You are looking for a part-time job and have applied at Bright Lights, a flashlight manufacturing company. As part of the interview for the job, the president of the company tells you that concave mirrors are used to make flashlights. Then she hands you a concave mirror and asks if it would be a good mirror for a flashlight. Your chances for the job will depend upon your answer.

Problem

Determine quantitatively whether this mirror will make a good flashlight.

Solution to the Problem Score ____

The focal length is aproximately 24.8cm. This would not be a good mirror for a flashlight unless the mirror was for a larger flashlight.

Commentary

The student provides a quantitative solution to the problem and supports it with the result in the analysis. The student makes reference to the focal length being too large for the mirror to make a good flashlight. It is left to the marker to infer the location of the bulb in relation to the mirror and how big a "larger flashlight" is. The evaluation is poorly made because it is too general.

Summary Comment

The student understands the problem, presents a well-organized procedure, collects data, and treats the data correctly. The student provides a valid solution to the problem even though minor details are overlooked. The student makes a weak attempt to relate the solution to the real world.

Student Example 2

This response would receive a score of 13 out of 16.

Procedure

Scoring Criteria

4

The problem is **thoroughly understood**. An **appropriate** and **practical** procedure is presented in a clear **sequence**. The data to be collected would be **accurate** and would **solve** the problem. Any omissions or inconsistencies do not hinder the communication of the procedure.

You may find it helpful to identify the important variables before providing your procedure.

Manipulated (independent) variable ~~[illegible]/[illegible]~~ Distance of object
Responding (dependent) variable Distance of image
Controlled variable(s) Distance of object.

Procedure Score ____

~~On the card board sheet place the card~~

Using the plasticene stand up the mirror, candle and card board sheet. Place the card board sheet a reasonable distance away from the mirror, (about 30cm-40cm). Light the cande and move it in between the mirror and the card board sheet until you see the image of the candle on the card board sheet. If you cannot see the image of the candle on the sheet move the sheet back more. Measure the distance between the mirror and the candle and the mirror and the card board sheet. Record this data in a chart. Set the mirror at a different distance ~~and~~ from the cardboard sheet and do this ~~again~~ in two more times. ~~Once~~

Commentary

The student thoroughly understands the problem and designs an appropriate and practical procedure. A clear sequence with concise instructions is presented by the student. Measuring the distance between the mirror and the candle and the distance between the mirror and the cardboard sheet will provide the data needed to solve the problem. The student also indicates multiple trials to improve the accuracy of the data.

Continued

Observations

Scoring Criteria

3

The data gathered are **mostly consistent** with the procedure. The observations and results are **mostly complete**: they may contain omissions or errors, but the problem is still solvable. Scientific conventions of communication are used.

Observations **Score** ____

Trial Number	Distance of object	Distance of image
1	16cm	36cm
2	16.5cm	39cm
3	18cm	29cm

Commentary

The student provides data consistent with the procedure. Column headings are clear. The student uses correct units but has used insufficient precision in the distance measurement. Distances should be measured to the nearest tenth of a centimetre with this procedure.

Continued

Analysis

Scoring Criteria

3

The analysis is **mostly organized** and **mostly understood**. The mathematical treatment of the observations and results is **generally correct**. The data are analyzed, but some errors or inaccuracies exist.

Analysis

focal lengthe for trial #1

$\frac{1}{f_1} = \frac{1}{D_{o_1}} + \frac{1}{D_{i_1}}$

$\frac{1}{f_1} = \frac{1}{16cm} + \frac{1}{36cm}$

$\frac{1}{f_1} = \frac{9}{144cm} + \frac{3}{144cm}$

$\frac{1}{f_1} = \cancel{\frac{144cm}{9}}\ \frac{11}{144cm}$

$f_1 = \frac{144\,cm}{11}$

$f_1 = 13.0909cm$

focal length for trial 2

$\frac{1}{f_2} = \frac{1}{D_{o_2}} + \frac{1}{D_{i_2}}$

$\frac{1}{f_2} = \frac{1}{16.5cm} + \frac{1}{39cm}$

$\frac{1}{f_2} = \frac{37}{429cm}$

$f_2 = \frac{429cm}{37}$

$f_2 = 11.594594594\ cm$

focal length for trial 3

$\frac{1}{f_3} = \frac{1}{D_{o_3}} + \frac{1}{D_{i_3}}$

$\frac{1}{f_3} = \frac{1}{18cm} + \frac{1}{29cm}$

$\frac{1}{f_3} = \frac{47}{522cm}$

$f_3 = \frac{522cm}{47}$

$f_3 = 11.10638298cm$

Score

average for focal length

$f_{av} = \frac{f_1 + f_2 + f_3}{3}$

$f_{ave} = \frac{13.09cm + 11.59cm + 11.106cm}{3}$

$f_{ave} = \boxed{9.2cm}$

the focal length is at 9.2cm.

Commentary

The student clearly organizes the analysis by showing all formulas, substitutions, and final answers with correct units. An averaging technique is demonstrated, but the student has incorrectly calculating 9.2 cm, rather than the correct value of 12 cm, in the final step.

Continued

Solution

Scoring Criteria

3

A **solution** to the problem is given that is **generally supported** by the analysis. The **evaluation** of the solution is **poorly** made.

Recall this information as you provide your solution to the problem.

Context

You are looking for a part-time job and have applied at Bright Lights, a flashlight manufacturing company. As part of the interview for the job, the president of the company tells you that concave mirrors are used to make flashlights. Then she hands you a concave mirror and asks if it would be a good mirror for a flashlight. Your chances for the job will depend upon your answer.

Problem

Determine quantitatively whether this mirror will make a good flashlight.

Solution to the Problem Score ______

This mirror would not be good for a flashlight. Its focal length is at 9.2 cm, this would make the flashlight too long. Errors could have occured in measureing the distance from the mirror.

Commentary

In the first sentence, the student provides a solution to the problem that is supported by the analysis. A source of error in distance measurements is identified. Although the student attempts to make a real-life connection, the statement "this would make the flashlight too long" is too general.

Student Example 3

This response would receive a score of 9 out of 16.

Procedure

Scoring Criteria

2

The problem is **understood**. A practical procedure with major omissions or errors, that could be followed only by someone who knew what was being looked for is presented. The data to be collected may be too **inaccurate** to solve the problem.

You may find it helpful to identify the important variables before providing your procedure.

Manipulated (independent) variable the mirror used
Responding (dependent) variable direction the light travels
Controlled variable(s) distance of candle to mirror

Procedure Score ______

1) Gather materials
2) light candle
3) moald plasticine until the mirror is at the same height as the flame (the mirror should be stuck about 2mm into the top of the plasticine so it stays)
4) Place the plarticine about 30 cm from the cardboard sheet.
5) Place the candle at 3 different distances in front of the plasticine (one at 3cm, 6cm and 9cm).
6) Observe if any of these distances can make the light more straight ahead, if any do work, move the sheet back and forth to see if the light stays focused.
7) Record any distance that works as how far the bulb should be away from the mirror in the flashlight.

Commentary

The student understands that the focal length of the mirror needs to be found. The procedure is incomplete because the student does not identify the measurements to be made. The method described—selecting 3, 6, and 9 cm—may be too inaccurate to solve the problem (depending on the focal length of the mirror).

Continued

Observations

Scoring Criteria

2

The data gathered **relate** to th procedure. The observations and results are **incomplete**, and it is likely that the problem cannot be solved wit these results. The use of scientific conventions of communication is **inconsistently** followed.

Observations

Score ______

Trial Number	Distance of candle to flame	Is the light focussed? (y/n)
1	3 cm	n
2	6 cm	y
3	9 cm	n

Commentary

The results are consistent with the procedure and are mostly complete. The precision of the 3, 6, and 9 cm is insufficient. Acceptable precision for distance measurements for this procedure is to the nearest tenth of a centimetre. The data collected are insufficient to solve the problem because no image distance measurements are made.

Continued

Analysis

Scoring Criteria

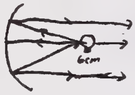
1

The analysis is **disorganized**. The mathematical treatment is **incomplete** and **inaccurate**.

Analysis

Score ______

At a distance of 6 cm, this is what the light rays are doing



This would make for a good flashlight.

Commentary

The student draws a ray diagram showing parallel reflected rays. There is no mathematical treatment to quantitatively determine the focal length of the mirror. Although the analysis is incomplete it can be inferred from the final sentence that the student recognizes the 6 cm as the focal point of the mirror and thus receives one mark.

Continued

Solution

Scoring Criteria

4

A **solution** to the problem is given, using appropriate scientific conventions of significant digits and units where appropriate. The solution is **thoroughly supported** by the analysis. The **evaluation** of the solution is **properly** made in terms of the believability of the solution and any errors in the procedure.

Recall this information as you provide your solution to the problem.

Context

You are looking for a part-time job and have applied at Bright Lights, a flashlight manufacturing company. As part of the interview for the job, the president of the company tells you that concave mirrors are used to make flashlights. Then she hands you a concave mirror and asks if it would be a good mirror for a flashlight. Your chances for the job will depend upon your answer.

Problem

Determine quantitatively whether this mirror will make a good flashlight.

Solution to the Problem Score ______

This mirror would make a good flashlight, as long as the bulb is 6 cm away from the mirror. This is because this is the distance at which the light shines almost straight ahead, which is what we want flashlights to do.

Commentary

The student solves the problem by stating that the mirror will make a good flashlight. This solution is supported by the diagram in the analysis and the statement "This is because this is the distance at which the light shines almost straight ahead, which is what we want flashlights to do." The student confidently applies a memorized fact, that light rays from an object at the focal point of a concave mirror are reflected parallel to the mirror's axis, to the task. An indication of the sources of error is not required in this evaluation because of the student's experimental design.

Student Example 4

This response would receive a score of 5 out of 16.

Procedure

Scoring Criteria

1

The problem is **poorly understood**. The procedure is **incomplete** and the method used to obtain the data is **inappropriate**. Sufficient description is provided that the marker can infer that the data, if collected, could have been used to solve the problem.

You may find it helpful to identify the important variables before providing your procedure.

Manipulated (independent) variable ____________

Responding (dependent) variable When light is Focussed, defined

Controlled variable(s) Candle stick as light source

Procedure Score ______

1. Collect all materials
2. light candle with match
3. Make a stand with plastercene place mirror firmly on top realitive to the flames height
4. Find at what distance from the wall the candle and the mirror make a good flashlight
5. Record results.

Commentary

The student shows some understanding of the problem. In step 3, the student places the flame along the axis of the mirror, and in step 4, the relative position of the candle to the mirror is identified as being significant. However, the procedure is incomplete because it does not identify any measurements to be made. The implied measurements from step 4 could be used to solve the problem.

Continued

Observations

Scoring Criteria

2

The data gathered **relate** to the procedure. The observations and results are **incomplete**, and it is likely that the problem cannot be solved with these results. The use of scientific conventions of communication is **inconsistently** followed.

Observations

Score ______

Trial Number	Distance of candle(flame) from Board (cm)	Distance of mirror from board (cm)
1	17	24,9
2		
3		

Commentary

The student provides data that are related to the procedure and that could provide a basis for solving the problem. However, these measurements are not d_0 and d_i but board to candle and d_i, and it is not likely the problem will be solved with these results. The student provides only one set of data. The student has correct units for the data, but the precision on the distance measurements is inconsistent.

Continued

Analysis

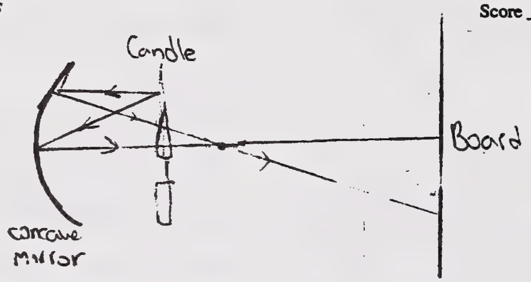
Scoring Criteria

1

The analysis is **disorganized**. The mathematical treatment is **incomplete** and **inaccurate**.

Analysis

Score ______



f = ? $\frac{1}{f} = \frac{1}{do} + \frac{1}{d_i}$

do = 0.007m $\frac{1}{f} = \frac{1}{0{,}007m} + \frac{1}{0.0245m}$

d_i = 0.0245m $\frac{1}{f} = 142{,}86m + 40.82m$

$\frac{1}{f} = \frac{1}{183{,}68}$

f = 0.0054m

Commentary

The student writes down the correct formula for focal length. The substitution of values is not supported by the data collected. The mathematical error in the second last line is significant. The student states the final answer with the incorrect number of significant digits.

Continued

Solution

Scoring Criteria

1

A **solution** to the problem is given, but is **not supported** by the analysis. **Evaluation** of the solution is **missing**.

Recall this information as you provide your solution to the problem.

Context

You are looking for a part-time job and have applied at Bright Lights, a flashlight manufacturing company. As part of the interview for the job, the president of the company tells you that concave mirrors are used to make flashlights. Then she hands you a concave mirror and asks if it would be a good mirror for a flashlight. Your chances for the job will depend upon your answer.

Problem

Determine quantitatively whether this mirror will make a good flashlight.

Solution to the Problem Score _______

This mirror will not make a good flashlight this is because the mirror is not curved enough. If the mirror was more curved there would be a more defir and clearer light present which I didn't find while doing this experiment

Commentary

The student provides a solution to the problem but does not make any reference to the focal length of 0.0054 m as found in the analysis. Thus, the solution is not supported by the analysis. The student makes no attempt at evaluating the validity or believability of the solution.

Performance Task 3—Water Waves

The task as it appears in the Student Booklet:

Context

You are spending a summer day at a lake. You have left your towel and radio just above the water on the shore while you are swimming. Suddenly, a large powerboat goes by 30 m from the shore and creates a large wave. How much time do you have to rescue your radio and towel before the wave reaches them?

Problem

Determine the time for the wave to reach the shore.

Materials

You may use some or all of the following:

- 1 large bucket or ripple tank
- water
- model boat
- stop watch
- ruler
- marble
- metre stick
- string
- speed conversion graph

Instructions

You have 20–30 minutes to design and use a procedure to solve the problem.

- Describe your *procedure*.

- Communicate your *observations*.

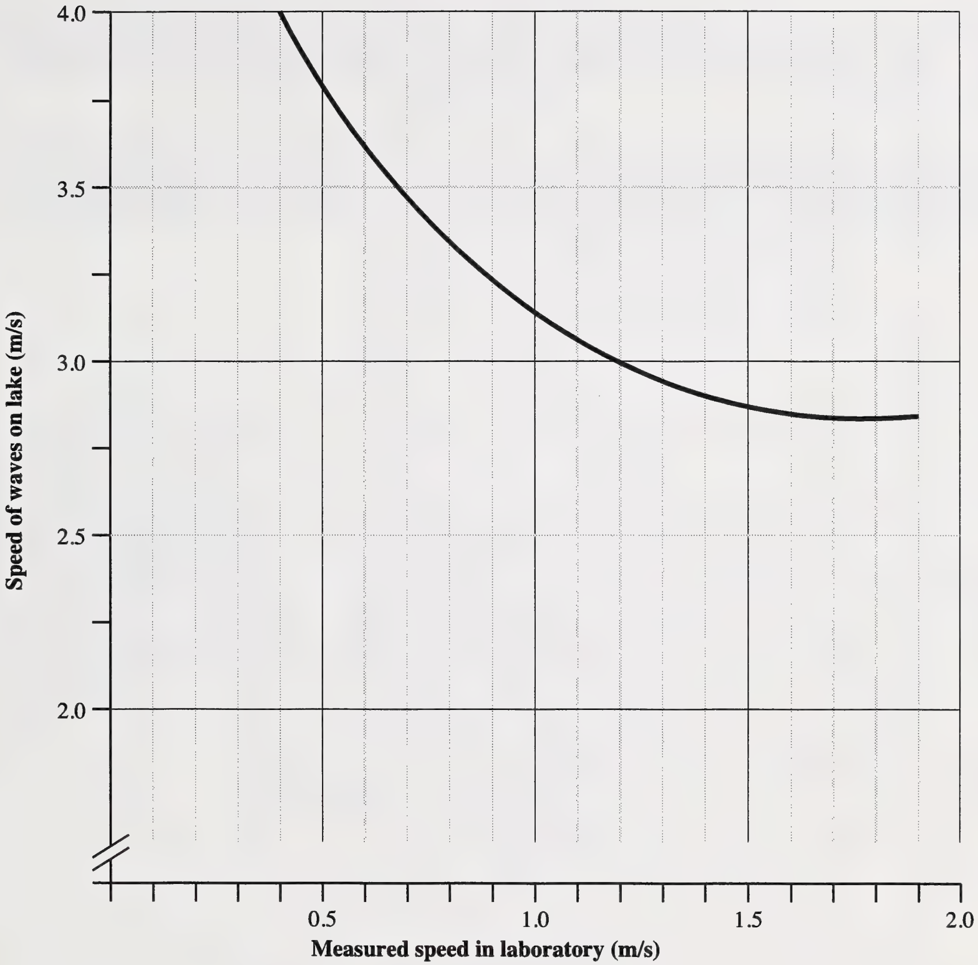
- *Analyze* your results. Include all necessary calculations, graphs, etc., to solve the problem.

- *Solve* the problem and *evaluate* your solution.

- Remember that your work will be scored for *procedure*, *observations*, *analysis*, and *solution to the problem*.

Before leaving this station, put all items of equipment back where you found them. **Leave the station as it was when you arrived.**

Speed Conversion Graph



General Trends

Students using a knowledge approach to physics found this task to be challenging. They tended to miss the wave speed entirely by tying the string to the boat and then measuring the speed of the boat. These students also tended to ignore the speed conversion graph preferring to use simple proportion ratios.

For the solution to the problem to receive a four, the student needs to state the time required for the wave to reach the shore, make reference to sources of error in determining this time and connect this time to the real world. Error discussion is required here, as in *Dart Gun*, because a numerical value is required as the solution to the problem.

Student Example 1

This response would receive a score of 15 out of 16.

Procedure

Scoring Criteria

4

The problem is **thoroughly understood**. An **appropriate** and **practical** procedure is presented in a clear **sequence**. The data to be collected would be **accurate** and would **solve** the problem. Any omissions or inconsistencies do not hinder the communication of the procedure.

You may find it helpful to identify the important variables before providing your procedure.

Manipulated (independent) variable Distance traveled
Responding (dependent) variable Time
Controlled variable(s) Distance to travel

Procedure Score ______

Set out your materials. Fill the ripple tank with about 1 - 2 cm of water.

Measure 30 cm away from one side of the tank and place your marble at that point.

Then take your model boat and drop it gently into the water at the 30 cm point where the marble is. At the exact time the boat hits the water start your stopwatch. When the wave hits the side of the ripple tank stop your stop watch

Mark down the time it takes to reach the side of the ripple tank. Convert this into $\frac{cm}{s}$ and then into $\frac{m}{s}$.

Now use your Speed conversion graph to find out the speed of the wave in the lake.

Use the waters velocity in the lake to find out the time it takes for the wave to travel 30 m and soak your radio and towel

Do this three times and find the average time.

Note: Make sure to drop the model boat in the same spot for each trial.

Commentary

The student thoroughly understands the problem and designs a practical procedure with a clear, concise sequence. Measurements of the control (distance the wave travels) and the time it takes for the wave to reach the other side are identified. The student also indicates that the experiment must be performed a number of times, thus improving the accuracy of the data.

Continued

Observations

Scoring Criteria

4

The data gathered are **consistent** with the procedure. The observations and results are **complete**. They are **clearly** and **logically recorded**. The observations communicate multiple trials, where appropriate, to solve the problem. Correct scientific conventions of communication are evident in **precision** of measurements and **units**.

Observations

Score ____

Trial	Time	Displacement
1	1.87 s	30 cm
2	1.78 s	30 cm
3	1.78 s	30 cm

$V = \frac{d}{T}$

Commentary

The student provides data consistent with the procedure. The student lists the data in chart form with clear labels and uses correct scientific conventions in both units and precision.

Continued

Analysis

Scoring Criteria

4

The analysis is **well organized** and **thoroughly understood**. The mathematical treatment of the observations and results is **correct**, including formulas, calculations, graphs, significant digits, and units, etc. The data are **accurately** and **completely** analyzed. Minor errors may exist in the analysis.

Analysis Score ______

Trial — Velocity in $\frac{cm}{s}$

1/ $v_1 = \frac{d}{T}$ $v_1 = \frac{30\,cm}{1.87\,s}$ $v_1 = 16.0\,\frac{cm}{s}$

2/ $v_2 = \frac{d}{T}$ $v_2 = \frac{30\,cm}{1.78\,s}$ $v_2 = 16.9\,\frac{cm}{s}$

3/ $v_3 = \frac{d}{T}$ $v_3 = \frac{30\,cm}{1.87\,s}$ $v_3 = 16.0\,\frac{cm}{s}$

Conversion to $\frac{m}{s}$

Trial

1/ $16.0\,\frac{cm}{s} \cdot \frac{1\,m}{100\,cm} = 0.16\,\frac{m}{s}$

2/ $16.9\,\frac{cm}{s} \cdot \frac{1\,m}{100\,cm} = 0.169\,\frac{m}{s}$

3/ $16.0\,\frac{cm}{s} \cdot \frac{1\,m}{100\,cm} = 0.16\,\frac{m}{s}$

Average of Velocities

$$V_{ave} = \frac{V_1 + V_2 + V_3}{3}$$

$$V_{ave} = \frac{0.16\,\frac{m}{s} + 0.164\,\frac{m}{s} + 0.16\,\frac{m}{s}}{3}$$

$$V_{ave} = \frac{0.489\,\frac{m}{s}}{3}$$

$$V_{ave} = 0.163\,\frac{m}{s}$$

∴ My average Velocity in the laboratory is $0.16\,\frac{m}{s}$

∴ Using the speed conversion graph I found the speed in the lake to be approximately $6.0\,\frac{m}{s}$

$$T = \frac{d}{v}$$

$$T = \frac{30\,m}{6.0\,\frac{m}{s}}$$

$$T = 5\,s$$

∴ I have about 5.0 s to
5 get my radio and towel.

Commentary

The student provides an analysis that is well organized and that shows all formulas, substitutions, calculations, and a correct averaging technique. The data used is consistent with the observations and the student correctly converts the solution using the graph. Although there are no errors in this analysis a 4 may be awarded for analysis that contains minor errors.

Continued

Solution

Scoring Criteria

3

A **solution** to the problem is given that is **generally supported** by the analysis. The **evaluation** of the solution is **poorly** made.

Recall this information as you provide your solution to the problem.

Context

You are spending a summer day at a lake. You have left your towel and radio just above the water on the shore while you are swimming. Suddenly, a large powerboat goes by 30 m from the shore and creates a large wave. How much time do you have to rescue your radio and towel before the wave reaches them?

Problem

Determine the time for the wave to reach the shore.

Solution to the Problem Score ______

It will take the wave about 5.0 s to reach the shore.

There are some things that could make this measurement inaccurate.

1) The timer might not start or stop the stop watch at the time they should

2) The boat might not be dropped at the same place each time

Commentary

In the first statement, the student indicates a solution that is consistent with and supported by the analysis. An evaluation of the solution is given by the student by providing some points that would make the experiment more accurate. The student receives a 3 and not a 4 because the response is weak in relating the reasonableness of the solution to the context.

Summary Comment

The student clearly understands the problem and is able to design a practical procedure that solves the problem. The student's work is concise and easy to understand, and communication of correct scientific convention is evident throughout. The student is confident in physics, and this is evident in the work the student demonstrates.

Student Example 2

This response would receive a score of 11 out of 16.

Procedure

Scoring Criteria

3

The problem is **well understood**. An **appropriate** and **practical** procedure is presented, but the data to be collected would be **insufficient** to solve the problem. Any omissions or errors in the sequence affect the validity of the data to be collected.

You may find it helpful to identify the important variables before providing your procedure.

Manipulated (independent) variable ________________

Responding (dependent) variable ________________

Controlled variable(s) ________________________

Procedure **Score** ______

1. Fill tank half full with water
2. drop a pebble into the water
3. calculate time it takes For the wave to travel from the rock to the side.
4. measure the distance the rock is From the side you measured the time to
5. calculate velocity in laboratory
6. use Speed conversion graph to calculate speed of waves in lakes
7. calculate time it takes For the wave to reach the shore.

Commentary

The student provides a step-by-step procedure that is appropriate to solve the problem by measuring distance and time, which are necessary to calculate speed. Multiple trials are not indicated in the procedure. This reduces the validity of the data being collected.

Continued

Observations

Scoring Criteria

3

The data gathered are **mostly consistent** with the procedure. The observations and results are **mostly complete**: they may contain omissions or errors, but the problem is still solvable. Scientific conventions of communication are used.

Observations

Score ______

1. First time I dropped the rock in the water, the wave travel 0.3 m in 1.5 s
2. Second time I dropped the rock in the water, the wave travelled 0.27 m in 1.21 s.
3. third time I dropped the rock in the water, the wave travelled 0.3 cm in 1.49 s.

Commentary

The student provides data consistent with the procedure for multiple trials in statement form rather than in a data chart, which is acceptable. There is an inconsistency in the precision used in recording distance (0.3 m and 0.27 m) and time (1.5 s and 1.21 s).

Continued

Analysis

Scoring Criteria

2

The analysis has **some** level of **organization** and shows **some understanding**. The mathematical treatment of the observations and results is only **partially correct**. The calculations may be inaccurate for the observations obtained.

Analysis Score ______

1. velocity of wave one

$v = \frac{d}{T}$

$v = \frac{0.3\,m}{1.5\,s}$

$v = 0.2\,\frac{m}{s}$

2. velocity of wave two

$v = \frac{d}{T}$

$v = \frac{0.27\,m}{1.21\,s}$

$v = 0.22\,\frac{m}{s}$

3. velocity of wave three

$v = \frac{d}{T}$

$v = \frac{0.3\,m}{1.49\,s}$

$v = 0.2\,\frac{m}{s}$

$\therefore$ avg. velocity is $0.207\,\frac{m}{s}$.

4. Find time for wave to reach shore

$v = \frac{d}{T}$

$T = \frac{d}{v}$

$T = \frac{30\,m}{4.45}$

$T = 6.74\,s$

$\therefore$ It will take approx 6.74 s before the wave hits the shore.

Commentary

The student treats the data partially correctly by providing formulas, substitutions, and calculations; however, the averaging method is missing. As well, the student produces and uses the value of 4.45 (no units) with no explanation of how this value was obtained. The scientific convention of significant digits is not followed.

Continued

Solution

Scoring Criteria

3

A **solution** to the problem is given that is **generally supported** by the analysis. The **evaluation** of the solution is **poorly** made.

Recall this information as you provide your solution to the problem.

Context

You are spending a summer day at a lake. You have left your towel and radio just above the water on the shore while you are swimming. Suddenly, a large powerboat goes by 30 m from the shore and creates a large wave. How much time do you have to rescue your radio and towel before the wave reaches them?

Problem

Determine the time for the wave to reach the shore.

Solution to the Problem Score______

You will have 6.7s before the wave, from a boat 30m away, will reach you on shore. In that time you must get out of the way.

Commentary

The student provides a solution that is supported by the analysis. The student has attempted a real-life application of the solution by indicating the time it takes to get "out of the way" but has not described sources of error in the experimental design.

Student Example 3

This response would receive a score of 7 out of 16.

Procedure

Scoring Criteria

2

The problem is **understood**. A practical procedure with major omissions or errors, that could be followed only by someone who knew what was being looked for is presented. The data to be collected may be too **inaccurate** to solve the problem.

You may find it helpful to identify the important variables before providing your procedure.

Manipulated (independent) variable speed of block
Responding (dependent) variable time taken to travelled
Controlled variable(s) same bucket, water etc

Procedure **Score** ______

Apparatus, place water in bucket

1. wrap marble in string
2. place block at one end of bucket (..
3. place marble at other end of bucket w/string on bucket edge
4. time how long it takes block to reach
5. Record distance travelled & time
6. Repeat 2 times.

Commentary

The procedure suggested is practical in that it describes the need for multiple trials and the need for a fixed distance for each trial. In addition, the student shows understanding by collecting distance and time data, but the data is for a block moving across the bucket and not the wave. The student does not provide an appropriate procedure for accurately solving the problem.

Continued

Observations

Scoring Criteria

2

The data gathered **relate** to the procedure. The observations and results are **incomplete**, and it is likely that the problem cannot be solved with these results. The use of scientific conventions of communication is **inconsistently** followed.

Observations

distance - 20cm

[illegible]

trial 1. 8.68
2 6.53
3. 9.29
4. 8.57

Score ______

Commentary

The student's observations relate to the procedure. The student records multiple trials with appropriate precision. The student uses a fixed distance of 20 cm. No units for the numbers in any of the trials are provided, and there is no indication of what the numbers represent.

Continued

Analysis

Scoring Criteria

1

The analysis is **disorganized**. The mathematical treatment is **incomplete** and **inaccurate**.

Analysis **Score** ______

$$\text{average} = \frac{\Sigma\ \text{times}}{4}$$

= [illegible]

$$v = \frac{d}{t}$$

$$v = \frac{0.2\,\text{m}}{8.2675} = 0.02419\ \text{m/s}$$

equivalent to over 4 m/s in lake

$$5\ \text{m/s} = \frac{3\,\text{m}}{t} \qquad t = 1.66\ \text{s}.$$

Commentary

The student uses data that are consistent with the observations and uses a speed formula appropriately. The student does not show an averaging technique (the work is erased). The conversion from the calculated speed, 0.02419 m/s, to the speed on the lake of 5 m/s is inaccurate. The student uses significant digits incorrectly.

Continued

Solution

Scoring Criteria

2

A **solution** to the problem is given, that is **generally supported** by the analysis. **Evaluation** of the solution is **ignored**.

Recall this information as you provide your solution to the problem.

Context

You are spending a summer day at a lake. You have left your towel and radio just above the water on the shore while you are swimming. Suddenly, a large powerboat goes by 30 m from the shore and creates a large wave. How much time do you have to rescue your radio and towel before the wave reaches them?

Problem

Determine the time for the wave to reach the shore.

Solution to the Problem **Score** ___.___

1.66 s. to reach shore

Commentary

The student provides a solution to the problem with correct units. The student does not attempt to relate the physics of the question to its implications in reality. There is no indication of any sources of error in the collection of data.

Student Example 4

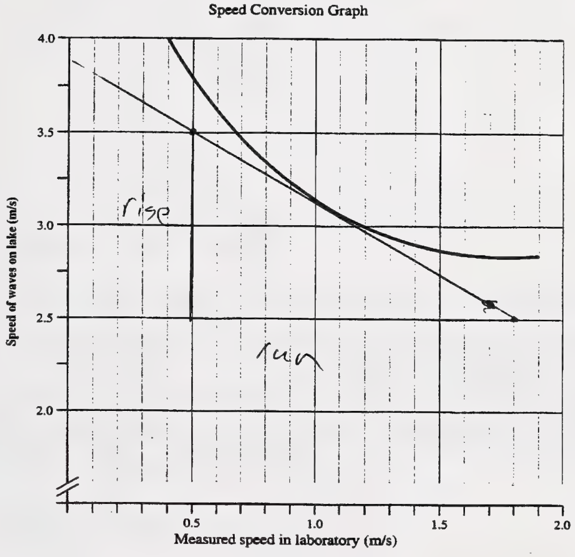
This response would receive a score of 5 out of 16.

Procedure

Scoring Criteria

2

The problem is **understood**. A practical procedure with major omissions or errors, that could be followed only by someone who knew what was being looked for is presented. The data to be collected may be too **inaccurate** to solve the problem.



Phvs/SSR PBA4Dp2

You may find it helpful to identify the important variables before providing your procedure.

Manipulated (independent) variable ____________

Responding (dependent) variable ____________

Controlled variable(s) ____________

Procedure Score ______

(1) measured distance across the water tub

(2) timed how long it ~~we~~ took for wave to cross ~~and~~ reflect and return.

Commentary

The student shows some understanding of the problem by measuring distance and time. The response contains major omissions in failing to identify any controls or multiple trials.

Continued

Observations

Scoring Criteria

1

The data gathered **relate** to the procedure. Scientific conventions of communication are absent.

Observations Score ______

It took the wave 1.5 sec to make the 49 cm distace so the wave had a velocity of 3.3 m/s, ~~I found the slope of the speed conversion graph to be .77~~ using ~~Fr~~ $v = f \cdot \lambda$

~~since The frequencie was 1 the wave length was 3.3 m~~

~~The the distance the wave traveled at on the lake side was 30 m~~

so it would take the wave $v = \frac{d}{t}$ $\frac{d}{v} = t$ $t =$ 9.1 seconds to reach the beach

Commentary

A single distance and time measurement that relate to the procedure are made. Scientific conventions are ignored in the units of time and in the precision of the distance measurements.

Continued

Analysis

Scoring Criteria

1

The analysis is **disorganized**. The mathematical treatment is **incomplete** and **inaccurate**.

Analysis Score ______

Commentary

The student provides the analysis under Observations, in the second half of the first sentence, “So the wave had a velocity of 3.3 m/s” and the first half of the last sentence, “so it would take the wave $v = d/t$, $d/v = t$, $t < 9.1$ seconds . . . .” The stated value of 3.3 m/s should be 0.33 m/s. The student does not use the speed conversion graph to obtain the speed of the wave on the lake before calculating the time. With a correct value from the conversion graph, this could give a valid answer. The formula $v = f\lambda$ is irrelevant to the problem and can be ignored.

Solution

Scoring Criteria

1

A **solution** to the problem is given but is **not supported** by the analysis. **Evaluation** of the solution is **missing**.

Recall this information as you provide your solution to the problem.

Context

You are spending a summer day at a lake. You have left your towel and radio just above the water on the shore while you are swimming. Suddenly, a large powerboat goes by 30 m from the shore and creates a large wave. How much time do you have to rescue your radio and towel before the wave reaches them?

Problem

Determine the time for the wave to reach the shore.

Solution to the Problem Score ______

Commentary

The solution is provided in the last sentence under observations where the student states “$t < 9.1$ seconds to reach the beach.” There is no evaluation provided.

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